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THESIS

A FRAMEWORK FOR A DISTRIBUTED DECISION SUPPORT NETWORK

by

Dan S. McQuay

September 1995

Principal Advisor: Hemant Bhargava

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Decision support systems have traditionally been developed as stand alone applications which conform to a specific users hardware and software requirements. This leads to reduced sharing and reuse of the application as well as the data, models, and algorithms incorporated within the application. The Internet, WWW, and enabling technologies allow for the dissemination of multimedia information to support diverse groups of remote users. This thesis demonstrates that decision support technologies can also be made available to users of a heterogeneous network in a similar manner.

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A FRAMEWORK FOR A DISTRIBUTED DECISION SUPPORT NETWORK

Dan S. McQuay
Captain, United States Marine Corps
B.S., University of Maryland, 1988

Submitted in partial fulfillment
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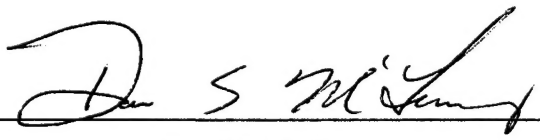
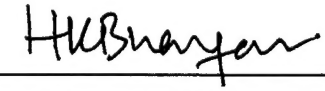
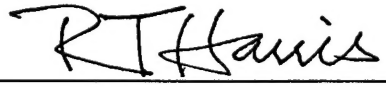
Author: 

Dan S. McQuay

Approved by: 

Hemant Bhargava, Principal Advisor

Kishore Sengupta, Associate Advisor



Reuben T. Harris, Chairman
Department of Systems Management

ABSTRACT

This thesis develops a concept for integrating decision support technologies with global computer networks. It introduces a new paradigm for the distribution and use of algorithms, decision support applications, models, and simulations. Under this paradigm, all mechanisms to allow for interactions between providers of technologies and consumers who wish to use them are facilitated by a distributed decision support server. Additionally, this thesis analyzes the concept of distributing decision technologies as a service vice a software product. It develops the initial framework architecture and proposes an infrastructure for a distributed decision support network.

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TABLE OF CONTENTS

LIST OF ACRONYMS

ADS	Advanced Distributed Simulation
API	Application Program Interfaces
ARPA	Advanced Research Projects Agency
ATD	Advanced Technical Demonstration
ATM	Asynchronous Transfer Mode
C4I	Command, Control, Communications, Computer and Intelligence
CGI	Common Gateway Interface
CIM	Corporate Information Management
CINCS	Commander-in-Chiefs
CMIP	Common Management Information Protocol
CMIS	Common Management Information Service
COE	Common Operating Environment
COI	Community of Interest
COMPASS	Common Operational Modeling Planning and Simulation Strategy
CORBA	Common Object Request Broker Architecture
COTS	Commercial-off-the-Shelf
DCP	Distributed Collaborative Planning
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DOE	Department of Energy

DCE	Distributed Computing Environment
DDR&E	Director, Defense Research and Engineering
DDSN	Distributed Decision Support Network
DDSS	Distributed Decision Support Server
DIS	Distributed Interactive Simulation
DMSO	Defense Modeling and Simulation Office
DNS	Domain Name Server
DSB	Defense Science Board
DSI	Defense Simulation Internet
E-MAIL	Electronic Mail
EDI	Electronic Data Interchange
ETMO	Education, Training, and Military Operations
EXCIMS	Executive Council for Modeling and Simulation
FTP	File Transfer Protocol
GOSIP	Government OSI Profile
GUI	Graphical User Interface
HLA	High Level Architecture
HTML	Hypertext Mark-up Language
HTTP	Hypertext Transfer Protocol
IG	Inspectors General
IMSRR	An Interim M&S Resource Library
ISDN	Integrated Services Digital Network

ISO	International Standards Organization
JTF	Joint Task Force
LAN	Local Area Network
M&S	Modeling and Simulation
NIDR	Network Information Discovery and Retrieval
NII	National Information Infrastructure
NIST	National Institute of Standards and Technology
NNTP	Network News Transfer Protocol
OSI	Open Systems Interconnection
P&L	Projects and Logistics
PFDL	Parameterized Format Description Language
R&D	Research and Development
SADT	Structured Analysis and Design Technique
SIMNET	SIMulation NETwork
SMTP	Simple Mail Transfer Protocol
SNMP	Simple Network Management Protocol
SQL	Structured Query Language
T&E	Test and Evaluation
TAFIM	Technical Architecture Framework for Information Management
TCP/IP	Transmission Control Protocol/Internet Protocol
TRM	Technical Reference Model
UDP	User Datagram Protocol

URL	Uniform Resource Locator
USD(A&T)	Under Secretary of Defense (Acquisition and Technology)
VV&A	Validation, Verification, and Accreditation
VV&C	Verification, Validation,, and Certification
WAIS	Wide Area Information Server
WAN	Wide Area Network
WMTADS	Waste Management Technology Analysis and Decision Support
WWW	World-Wide Web

I. INTRODUCTION

"Defense modeling and simulation will provide readily available, operationally valid environments...to train jointly,...formulate operational plans, and assess warfighting situations." DoD EXCIMS,
March 1992

"We have the following strategic requirements for Modeling and Simulation... direct interface capability with operational C4I systems (comms, ADP, ADA)"
Brig Gen Michael C. Short, USAF
Director of Training, U.S. Atlantic Command
November 1993

"The organization that will excel ... will be those that manage information as a major resource" (Synott, 1981)

A. BACKGROUND

The purpose of this thesis is to develop a framework architecture for the distribution of decision support technologies[1] in a client server environment over a network using Transmission Control Protocol/Internet Protocol (TCP/IP). The open architecture design of TCP/IP has enabled the dissemination of information over a global network through the use of Network Information Discovery and Retrieval (NIDR) tools such as SMTP, FTP, WAIS, and TCP/IP applications such as Telnet and Network news. (Sprague, et al., 1993) These tools provide for a friendly user interface for the transfer of electronic information. The World Wide Web (WWW) has allowed the functionalities of these different applications to be combined under a single integrated browser application. (Berners-Lee, et al., 1994) By means of a simple scripting language the functionalities of these applications are now being used in conjunction with other software applications. The HyperText Transfer Protocol

[1]Throughout this thesis, *decision support technologies* and *decision technologies* are used to refer to a variety of software used to support decision making and modeling.

(HTTP) and HyperText Mark-up Language (HTML) has created an opportunity to exploit the functionalities of TCP/IP applications. (Berners-Lee, 1993)

The use of computer support to aid in decision making is required in many situations due to the volume of data and/or the time sensitive nature of the decision. Development of an application specific DSS is a lengthy and costly process. The models and algorithms must be verified and validated with valid data sets. Applications are continuously updated due to changes in the environment, changes in data requirements, and development of better algorithms. The life of a decision technology is usually short, as it is may only support one specific decision. This technology is thus archived and the models and algorithms used within the technology are lost and unavailable to users that may need to make the same or similar decision. Many organizations feel that it is not cost effective to buy or build DSS's for a specific decision process. (Sprague, 1980) This suggests that some applications may be better served as a service rather than a product. The customer could use the application and not be concerned with the management issues associated with owning the software product. This service could be provided by constructing a Distributed Decision Support Network (DDSN) which would allow a consumer to connect to and execute an application through simple hypertext links or a Graphical User Interface (GUI).

Industry and the Department of Defense (DoD) are moving rapidly to distributed systems, common operating environments, client server configurations, and object oriented databases. (Kral, January 1995) These technology upgrades will preclude the use of legacy/standalone decision technologies by all users of the distributed environment. To take full advantage of new technology, existing tools will need to be re-engineered to operate within the new operating environment. This is likely to be a timely and costly evolution. An alternate solution would be to distribute the existing legacy DSS applications/tools to users of the distributed network.

B. OBJECTIVES

The goal of this thesis is to outline an architecture and propose an infrastructure to facilitate the distribution of decision technologies over a global network. This is done by

establishing the idea and concepts of operation of the DDSN; identifying the functionality required between all entities of the system; and modeling the activities associated with the distribution of decision technologies. Through a rapid prototyping methodology, the responsibilities and transactions of all entities of the DDSN, will be substantiated. Once the architecture is developed, it is the authors intent to identify current capabilities and initiatives that relate to the architecture proposed, and to suggest areas where this technology can best be exploited by organizations in commercial industry and the DOD.

C. ORGANIZATION OF THESIS

This thesis is organized into six chapters and two appendices.

The first chapter contains the introduction and overview of this thesis. The second chapter conveys the motivation and arguments for building a framework to distribute decision support technologies. Chapter III examines the environment of the DDSN and identifies the roles and responsibilities of entities of the DDSN environment. Chapter IV examines the functions of the DDSS, identifies an architectural framework for the DDSN, and proposes an initial infrastructure for the DDSN. Both appendices of the thesis support Chapter IV. Appendix A discusses enabling technologies. Appendix B illustrates the IDEF 0 model developed to investigate the activities and the interaction of activities within the DDSS. Chapter V discusses the objectives of models and simulations within DoD and how the DoD can exploit the DDSN technology. Chapter VI is the thesis conclusion and suggest areas that require further research.

II. WHY BUILD A DISTRIBUTED DECISION SUPPORT NETWORK?

A. INTRODUCTION

Research in the decision sciences has resulted in the development of modeling and decision support applications that are useful in solving a variety of problems faced by individuals and organizations. (Davis, 1988) Decision Support Systems (DSS) aim to provide support for semi-structured and unstructured decisions in all stages of the decision process. DSS requires a unique interface between the user and internal databases, external databases, and analytical models. The dawn of the information age has brought greater demand for computer assistance in decision making due to the abundance of information, the ease with which it is obtained, and the time sensitive nature in which decisions are made.

Enabling technologies (client server applications, object oriented design, work flow management tools) have reduced uncertainty in decision making by making data more readily available to decision makers at all levels of the organization. However, many decision makers are overwhelmed by the amount of new data and delay making a decision until the data can be understood. Furthermore, these technologies have also introduced complex interdependicies between the organizational structure and the information system. (Walton, 1989) These interdependicies have changed the organizational structure, which has redefined who makes the decisions within the organization. To adequately support the decision making process of today's organization, a variety of decision support applications need to be available to all users of the organization on demand. In addition to a suite of tools for known re-occurring decisions, organizations will require access to a repository of decision support technologies for unexpected and dynamic events introduced by the environment. This new paradigm suggests that the decision sciences should exploit these enabling technologies in the development, interface, and distribution of decision technologies.

The underlying idea of a DDSN is to create an electronic market for decision support applications. This market would allow decision support and modeling systems to be

delivered as a service rather than as a product. (Bhargava, et al., 1995) By distributing these technologies as services, it is believed five categories of resources that are traditionally used in modeling and decision making (data, models, simulations, solvers, and decision support packages) can be made available to all users of the network. This market will allow a multitude of users access to a diverse library of tools. Potential users of this service include research activities, academia (professors and students), military organizations, industry, as well as casual users who occasionally need problem solving or assistance in making a decision.

This chapter examines the ideas behind developing a DDSN and the benefits of distributing decision technologies as a service over a global network, such as the Internet.

B. ELECTRONIC COMMERCE

The emergence of the National Information Infrastructure (NII) and the development of Internet applications such as the WWW have brought much attention to electronic commerce. The ultimate goal of the NII in Electronic Commerce is the creation of a national electronic marketplace which is secure, open, affordable, easy to access, and easy to use. (Gebase et al., 1993)

1. Commercial Business and the WWW

Today, while surfing the WWW, you can order a pizza from Pizza Hut, visit the archives of the Library of Congress, read the San Jose Mercury News, view video clips, listen to music, and go shopping in the Internet Mall. There is no other medium that is accessible to such variety of services and on-line functionality. The WWW and the Internet have demonstrated a great commercial opportunity. Commercial business on the Internet is expanding expeditiously, even with moderate security in place. The commercial domain is the fastest growing Internet group, with more than 1,500 new companies connecting to the Internet each month. The commercial sector now makes up more than one-half of all domain names according to Internet Society figures. (Ellsworth, 1995) Figure 1 illustrates the large growth of the Internet and the WWW.

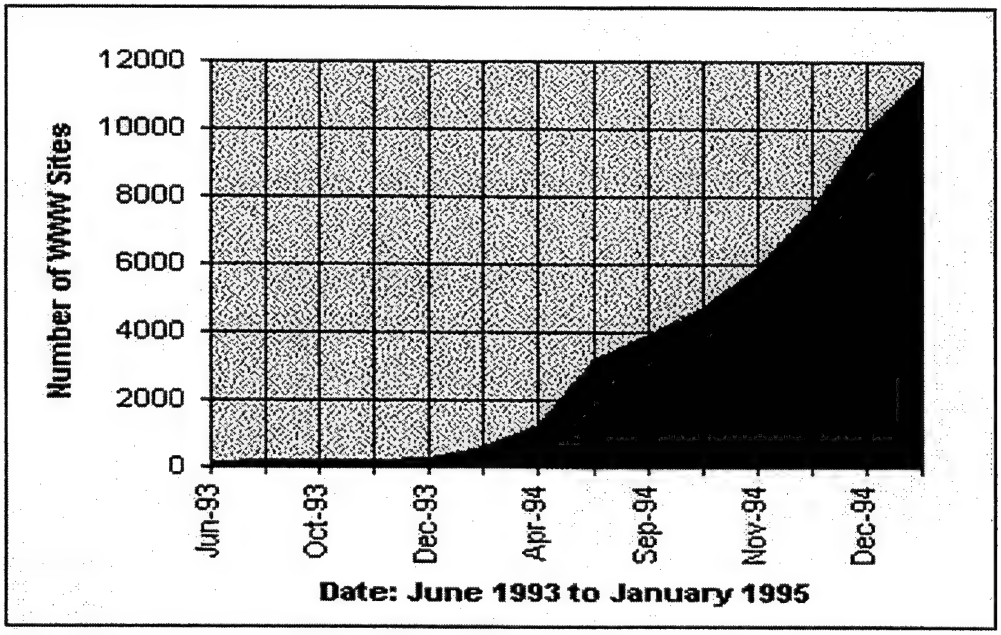

Figure 1. WWW Growth on the Internet

2. Electronic Data Interchange (EDI)

EDI is presently being used by many individuals and organizations to automate simple business decisions and financial transactions. These transactions have evolved to reduce paperwork and to increase the speed and availability of decision making information for business and government transactions. An advanced NII for Electronic Commerce will be able to support activities such as electronic funds transfer, government regulatory data interchanges, enterprise integration, and computer-supported collaborative work. (DoD, 1993) (Gebase, et al., 1995) The NII provides the enabling technologies for an electronic market of decision technologies. It would allow for decision technologies to be made available to users via a virtual repository. This repository of decision technologies will allow users to access and use decision technologies in conjunction with organizational data as well as external data sources. Potential users of this service include research activities, academia (professors and students), military organizations, industry, as well as casual users who occasionally need problem solving or assistance in making a decision.

C. ARGUMENTS FOR DISTRIBUTING DECISION SUPPORT TECHNOLOGIES

The Internet and associated NIDR tools have streamlined the transfer of electronic data, which includes executable software applications. (Abernathy, 1995) (Krol, 1994) Presently, a variety of public domain executable applications may be downloaded from sites around the world. However, this approach places additional requirements on both the developer and the user of the application. The developer must port the application for different platforms and the user must have the knowledge to install, configure, and maintain the application on his computer. The same holds true for decision technologies; a model or algorithm can not be processed in real time by a solver which does not exist on the clients machine.

The remote execution of these applications can be done by a procedure call through a Common Gateway Interface (CGI) which is used by the HTTP servers of the WWW. CGI allows for a simple user interface, making the execution of NIDR applications transparent to the user. The infrastructure of the DDSN and the providers decision technology can thus absorb a majority of task usually associated with the user. There are four main arguments for building such an infrastructure: *market potential*, *version management*, *the use vs. own*, and the *interoperability* or *shareability* argument.

1. The Market Potential Argument

By definition, there are limited--niche--markets for specific decision support applications/tools; the more specific a system is, the smaller its potential base of users. The lack of a large enough market for various decision technologies may often inhibit their development and availability. Many types of models are developed for ad hoc decisions for a specific organization, used once, put on the shelf, not maintained, and never used again. By providing technologies through a repository, such models would be available to a diverse set of users; expanding the market for such a model. The cost of reaching this market would be a fraction of the costs associated with conventional distribution channels. Users would be able to learn about and access a large number of decision technologies without obtaining the maintenance cost associated with the purchase and/or development of these applications.

They could browse freely, a yellow pages of technologies, identifying applications that would be beneficial in their decision making process.

2. The Version Management Argument

This argument is analogous with a client server application. For example, an organization buys a client server word processing application. The application is installed and maintained by the system administrator on one computer (application server). Users of the network use the application as if it were installed on their terminal. When a new version is installed or a bug is fixed in an application, the administrator updates the software at the server, the change is made transparent to all users. The cost and time required to implement the change decreases proportionally by the number of users of the application. The version management argument for a DDSN is that an electronic network would eliminate, or minimize, many of the costs and problems associated with updating software technologies when many copies and many versions of the same technology are physically distributed. Providers would not have to create and distribute multiple copies of a product since the application would be running at the providers computer. Updates and new releases would be made available simply by setting them up for execution and listing them in the DDSN database. All transactions would be done electronically, eliminating the need to package, bill, and mail via traditional methods.

3. The Use vs. Own Argument

Many potential consumers of decision technologies are unwilling to invest the time, money, and effort required to learn about, obtain, own, and use them, particularly when the decision problem is non-recurring. Further, buyers of decision technologies have to deal with the maintenance cost and updates required due to changes in model situation or change in data structures. By owning a software product the user must provide for the management of the product and must determine if the application is providing the added value that it was originally purchased for. A DDSN would allow a consumer to use a decision technology, when needed, and be free of the problems associated with owning and managing the software. This would promote a "pay" for use, vice purchasing and maintaining a copy of, a decision technology. The costs and time associated with learning about a decision

technology and using it as a service, would be modest compared with the costs associated with doing so with a conventional product.

4. The Interoperability and Shareability Argument

Even within organizations that have the resources to develop decision technologies, a repository of functional technologies offers an opportunity to share these technologies. This is particularly true when the organization is geographically dispersed and/or utilize a variety of hardware and software platforms. The DoD CIM initiative illustrates the need to combine information resources to reduce development and maintenance cost of information systems in future years. DoD and many commercial organizations of today are restructuring their organizational structure and redefining their business processes. (Appleton, 1993) This is due to enhanced technology and the need to minimize cost. Organizations of today are geographically dispersed, but share the same data resources. The DDSN would maintain a centralized library of decision technologies, allowing for decision technologies to be globally shared to dispersed organizations. This would increase awareness and knowledge of these technologies within an organization, allowing decision makers at all levels access to tools registered with the DDSN, regardless of the users hardware.

D. CONCLUSIONS

The ability to make expedient and correct decisions in today's computing environment requires the decision maker to have access to current data and the correct decision aids to process and visulize the data. Traditional research in the development of DSS's is being challenged by new technologies, reorganization of organizational structures, and redefining who really makes the decisions within the organization. Researchers and developers of the decision sciences will need to exploit these enabling technologies and re-engineer the way decision support applications are used, developed, and distributed to accommodate the modern organizational structure. A DDSN is one way in which existing technologies can be utilized by consumers of enterprise and global networks. This architecture will provide a high degree of interoperability and place minimal constraints on users' hardware and software environments, while allowing them to use technologies residing on many different

kinds of computer platforms. By creating an electronic market for decision support applications/tools the developers and researchers in the decision sciences can bring data, models, simulations, solvers, and decision support packages to the largest growing medium of information. This market will facilitate the advertisement as well as the use of these technologies; expanding the market and availability of these technologies.

III. CONCEPT OF OPERATION

A. INTRODUCTION

Electronic services in marketing, banking, and travel are becoming popular on the Internet via the WWW. These services require on-line interaction between the customer and the provider of the service. The provider of these services must also provide back-end processing to render the service to the customer. A few decision support technologies are also available on the WWW. An application called Waste Management Technology Analysis and Decision Support (WMTADS) is operated by the Department of Energy (DOE). A user can search DOE technologies for treating waste as well as search for specific industry solutions to the technological challenge of treating wastes.[2] (DOE, 1994) The back-end processing of this type of technology provides for all the interaction of all databases and analytical models of the providers DSS with the users provided input data. The Common Gateway Interface (CGI) allows for the transfer of input data to the provider, execution of the application, and the return of output data to the user. (NSCA, 1995) This allows for the distribution of the technology over a heterogeneous network using a common interface, but does not allow for interoperability between technologies.

One way to achieve interoperability between decision technologies across diverse hosts and operating systems is through a Common Operating Environment (COE). A COE consist of a special software layer, such as CRONUS, or a level of architecture, and object standardization as in the CORBA standard. (Kral, 1995) Interoperability between registered technologies of the DDSN would be achieved by constructing an architecture in which agents would mediate the transactions between the users (consumers and providers) and between different technologies. (Bhargava, et al., July 1995) To better understand the requirements of this architecture, the entities, transactions, and requirements of all entities must first be identified. This chapter develops the requirements and responsibilities of the entities of the DDSN environment and defines the transactions between entities of the DDSN.

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[2]WMTADS is available at URL: http://mwir.lanl.gov/.

B. THE DDSN ENVIRONMENT

The DDSN environment consist of the network, providers of decision technologies, consumers of decision technologies, and the Distributed Decision Support Server (DDSS) as illustrated in Figure 2.

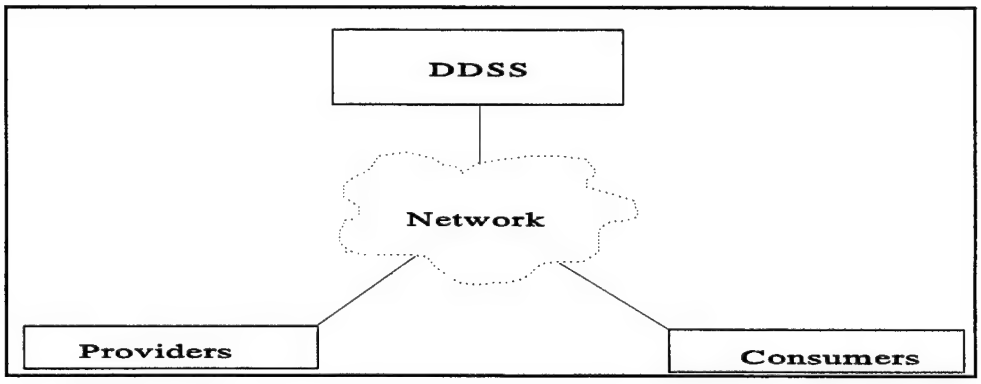

Figure 2. DDSN Environment

1. The Network

Allows for the physical transfer of data and the seamless interaction between different types of platforms. All entities of the environment are assumed to have access to the network. It is believed that different types of networks could facilitate the distribution of decision technologies, however, in this thesis the network discussed refers to the Internet.

2. Providers

Organizations, developers and/or individuals who desire their decision technology to be executable over the network, are considered providers. The provider is ultimately responsible for the functionality and dependability of the hardware and software for which the application runs. The provider must be able to define the structure for inputs and outputs of data required by the application. The provider is also responsible for the security of all input data from the consumer and the results produced from the application. At this time, two categories of providers exist, "Independent" applications and "Exclusive" applications.

a. "Independent" Applications

Providers that have provided a CGI for their applications which allow for the transfer of data and the execution of their application need only to register as a provider of the decision technology and register the application with the DDSS. The application can execute independently of the DDSS. The Uniform Resource Locator (URL) is used to interface the technology with the consumers of the DDSN.

b. "Exclusive" Applications

These providers must also register as a provider of the decision technology and register the decision technology itself. From the metadata obtained during registration, a series of HTML documents and CGI scripts will be developed by the DDSS to provide the needed interface between an HTTP server and the providers application (Bhargava et al, Germany June 95). Such applications executes exclusively in the DDSS environment. These interfaces will be technology dependent and will be constrained by the server support of the provider.

The provider is also responsible for maintaining a WWW browser application that supports the use of HTML forms; this is required for on-line registration of the provider as well as the technology. Depending on the type of application, the provider must also provide various servers (SMTP, FTP, Gopher, etc.) to allow for the transfer of input data as well as the return of output data to the consumer.

3. Consumers

A consumer of the DDSN is any person or organization who is in the market for computational decision support services and registers with the DDSS. The consumer is the end user of a decision technology which has been made available by a provider. A consumer is responsible for maintaining a WWW browser application that supports the use of HTML forms and NIDR tools to support the transfer of data as required. Consumers are responsible for the decisions made from the use of applications provided via the DDSN.

4. Distributed Decision Support Server (DDSS)

The DDSS provides the mechanisms which allow users to register, search for, connect to, and execute a decision technology. The DDSS is comprised of hardware, software, and the personnel assets which allows for the functionality of the network. It's purpose is to provide mechanisms for:

- On-line registration.
- Validation and verification of users and technologies.
- Help desk service.
- Creation of a common interface for exclusive technologies.
- Yellow pages of executable decision technologies.
- Translation of data structures to achieve interoperability.
- Support functions.

C. DDSN TRANSACTIONS

Transactions are initiated by the users of the DDSN using forms capable WWW browser (Netscape or Mosaic) and are mediated by agents of the DDSS. There are five categories of transactions within the DDSN environment: registration, log-in, connectivity to a decision technology, execution of a technology, and standard support functions (all other transactions required to support the first four categories of transactions).

1. Registration

All users of the network are required to register with the DDSS. This is done on-line via HTML forms or off line by E-mail. Registration is required to establish access via login and password to the services of the DDSS. Registration information is also used in the management functions required of the DDSS (billing, user reports, etc.). Providers must also register their decision technologies. The metadata information obtained during registration is used by the DDSS to verify, validate, accredidate, and construct a common interface as required. A validation message acknowledging the successful registration of a user or the state of a technology registration is sent to the provider by the DDSS via E-mail.

2. Logging In

Once a user is registered he simply logs into the system using the login and password established at registration. Once logged in the user can activate different agents within the DDSS to obtain the functionality (search, browse, edit registration information, use a technology) desired.

3. Connectivity to an Application

Once a technology is selected for use, the user initiates a request via a hypertext link or GUI to the DDSS to use said technology. Due to the stateless state of the HTTP the user is connected directly to the providers or warehouse server at this time. The user can read and learn more about the application and will then be asked to submit data and invoke execution of the application.

4. Execution

a. Input Data Transfer

Since the DDSS mediates all transactions, the data is sent via the DDSS, translation occurs, and the data is forwarded to the providers site. If the application is an independent technology, a translation process is not required, therefore, the input data is sent directly to the provider.

b. Invoking Execution

Once the data is made available to the provider, the application is invoked by either the consumer or the DDSS. Again this is dependent on the type of application. Use of an exclusive or invoking multiple applications would require the DDSS to monitor the state of each process and invoke execution once the processed data is received by the next application. An independent technology such as a WMTADS is invoked directly by the consumer as there is no need for translation of the output data for input to another application.

c. Receipt of Output Data

Once the application completes processing, the output data is sent back to the user and the DDSS. If it is a single transaction, the transaction is complete upon receipt of the output data. The consumer can then use the technology again or use another application.

For multiple application processes the output data is converted by agents at the DDSS and made available as inputs to the next application. Once the data is available at the next site the DDSS invokes execution of the application. This continues until the process is complete. The user will receive output data from each application used.

5. Standard Support

These transactions may be directly or indirectly initiated by the user. This support can be broken into two categories; help desk and management.

a. Help desk

Most of the functions of the DDSN are automated, however, a need exists for a mechanism to allow interaction between users and the DDSS staff. Initially, a help desk between users and the DDSS staff is envisioned using standard collaboration tools. These tools include E-mail, list serves, news groups, and PC video conference. A consumer can get help on the use of a decision technology and a provider can get assistance in registering a new technology.

b. Management

These transactions are those that are indirectly initiated by the users by simply using the network. This transactions consist of: user verification messages, technology usage reports, general management reports (consumers, providers, technologies available), and billing summaries.

D. CONCLUSIONS

This chapter is informative in nature and gives the reader a comprehension of the functions of the overall system. By identifying the roles and responsibilities of all entities and the transactions required between those entities, it is evident that the architecture and infrastructure of the DDSS is a determinant factor. The DDSS architecture will replace the software layer and the requirement for standardized data objects as used in the COE. It is believed that this will provide consumers with greater availability and flexibility in using technologies and external data sets in problem solving and decision support. Defining the

DDSN architecture is crucial in developing the mechanisms of the DDSS and is the focus of further research.

IV. DDSN ARCHITECTURAL OVERVIEW

A. INTRODUCTION

The term architecture and infrastructure are used diversely and interchangeably by professionals of information technology. Webster dictionary defines these terms as:

Architecture: The design or structure of something.

Infrastructure: The basic framework of a system or organization; fundamental facilities, as transportation and communication systems.

For the purpose of this thesis the following definitions are provided:

Architecture - The structure of components in a system, their interrelationships, and principles and guidelines governing their design and development over time.

Infrastructure - Resources (personnel, hardware, software, communications) used to achieve desired functionalities of a system.

This chapter presents an overview of the DDSN architecture and discusses DDSN infrastructure requirements by examining the requirements of each entity.

B. DEFINING THE DDSN ARCHITECTURE

The main objective of the DDSN architecture is to provide a truly heterogeneous system to users with minimal standards and conventions mandated. The architecture will allow users freedom of choice in use of a browser to access the DDSN and will not require compliance of standards and conventions in the development of decision technologies. The architecture will additionally allow for interoperability between applications by using translation mechanisms vice traditional COE technology. The initial DDSN architecture is based on common interface standards presently used by the WWW, additional components will be added at different stages of development to introduce new functionality. The initial architecture framework of the DDSN is defined by: defining the development stages of the

DDSN, reviewing objectives of the system, addressing technical considerations in achieving the system objectives, illustrating a reference architecture, and identifying required standards.

1. DDSN Development Stages

The development of the DDSN will be done in progressive stages due to different levels of complexity in functionality, evolving technologies, and some unresolved issues. Each development stage will allow more functionality to the users of the DDSN. Six levels of development are identified below: (Bhargava, et al., February 1995)

a. Level 0: A Repository of Available Decision Technologies

This is nothing more than a searchable electronic library of technologies in which the user can search for and learn about a decision technology.

b. Level 1A: A Repository of Executable Decision Technologies

This level introduces invoking execution of the technology by the consumer. After searching for an appropriate technology to solve a specific problem, the consumer can select one for use. The consumer can transfer data, invoke execution, and receive an output from the application, all of this by using a WWW browser.

c. Level 1B: Automating Setup of Decision Technologies

Level 1B automates the creation of the provider's interface. This is a software module which will automatically generate the scripts and files required from the metadata, provided during registration.

d. Level 2A: Using Multiple Applications to Solve Problems

This level will allow interoperability between technologies. The user initiates sequencing of technologies and transfer of data, but the DDSS will do the translation of data types.

e. Level 2B: User Defined Multiple Use of Technologies

The consumer initiates usage of a sequence of technologies to be used and transfers the initial data to the DDSS. The DDSS will have the knowledge about the technologies and where they exist to translate the data set and transfer it to the first technology. Upon completion, the output of the first technology is sent back to the DDSS, translation occurs and the data is sent to the next technology. This process continues until

the end of the sequence. The consumer receives an output from each technology used in the process, allowing the consumer to monitor progress.

f. Level 3: Use of Intelligent Agents to Select Technology for Use

The final level of development provides intelligent problem solving by using intelligent agents to choose the best technology alternative. The consumer would simply state the problem, the DDSS, using an intelligent search agent would then find the best technology or sequence of technologies to solve the given problem. The consumer would need only to transfer data, initiate execution, and receive output data.

2. Architecture Objectives of the DDSN

Chapter III of this thesis identified the transactions required within the DDSN. From those transactions we identify the following architecture objectives are identified.

a. Transparency

Network navigation, transfer of data, security of information, input formats, data storage, and search mechanism will be internal functionalities of the DDSS. This will create a seamless, transparent interface for the completion of these functions. The interface needs to be simplistic to fit the diverse user group of the DDSN.

b. Interoperability

The decision technologies accredited for use on the DDSN will allow for heterogeneous use. Additionally, the DDSS will allow interaction between applications to support sequencing of multiple technologies for problems that require multiple applications.

c. Uniformity

The user will see the same interface no matter what computer platform is used.

d. Flexibility/Extensibility

New technologies can be added to the network without any effect on existing technologies. From the users perspective, the network will provide a variety of technologies, used by a diverse set of users in changing environments.

e. Distributed Environment

Users, providers, and technologies will be geographically dispersed and connected by an electronic virtual heterogeneous network. This will allow for limited resource requirements to obtain decision support services any time, any place.

3. Technical Considerations

The idea behind a DDSN is based on new and evolving technologies and the development of software agents as translation mechanisms instead of a COE. Technical considerations will heavily influence the DDSN architecture and infrastructure. The DDSN architecture must allow for these future technologies and concepts to evolve.

a. Enabling Technologies

Appendix A identifies the enabling technologies that the author feels will be essential in the successful development of a DDSN.

b. Unique DDSN Software Development

The software agents and middleware which will provide for automatic registration and interoperability between applications are a critical success factor in the proof of concept and of the development of the DDSN. Requirements are presently being identified and options are being researched. (Bhargava, et al., July 1995)

4. Architectural Framework

The entities of the DDSN environment were previously introduced and require no further explanation. Figure 3 is introduced to illustrate a reference architecture of the DDSN. This architecture can be described as a conglomerate of provider nodes which allow their decision technologies to be accessed and used by a variety of consumer nodes interlinked and controlled by the DDSS node via a global network.

5. DDSN Standards and Conventions

A major goal of the DDSN idea is to increase availability of decision technologies to users of a global network. COE's require a suite of common tools on all users' machines. The DDSN idea would allow consumers to use browser applications of their choice; providers can build applications using proprietary software and run the application on the

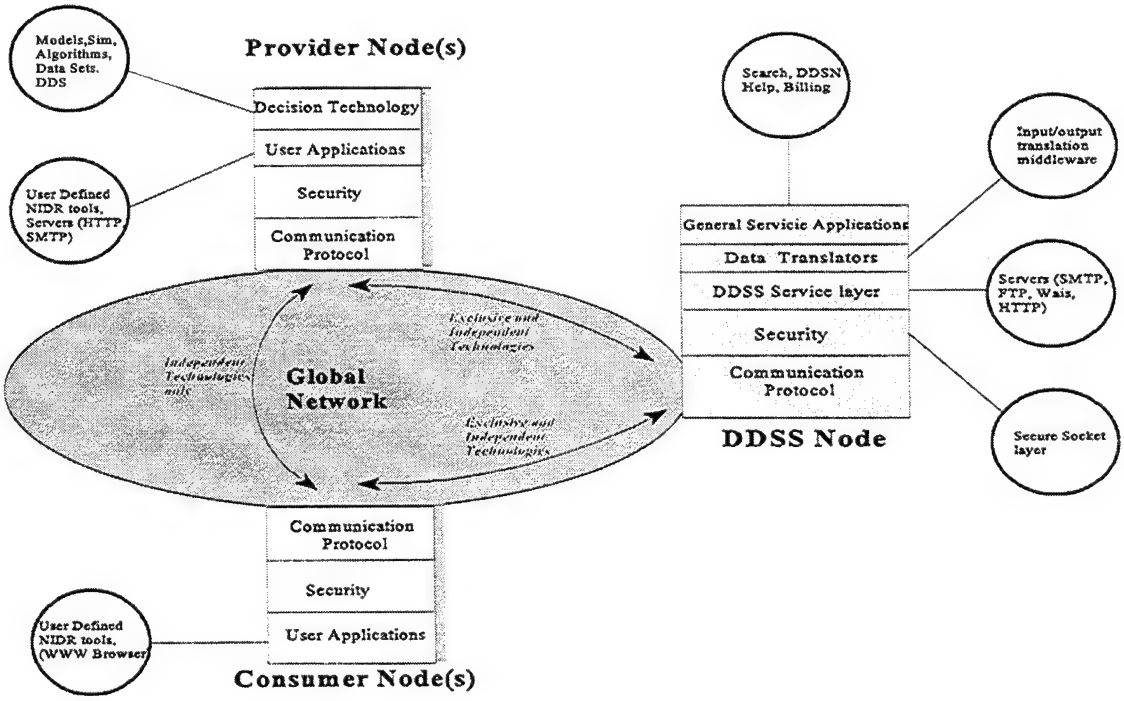

Figure 3. DDSN Reference Architecture

computer platform of their choice. We believe that the standards and conventions can be limited to the defacto standards used today by the Internet and WWW. To obtain minimal functionality, all users must initially have: connection to a network, a TCP/IP stack installed, a form's capable browser, and complete the registration process as a consumer or provider.

a. Layered Reference Model

An architecture from the perspective of a reference model is shown in Figure 4. This model was developed to identify standard services of the DDSN and to provide an elementary view of the DDSN for future discussions. The reference model is divided into four functional layers: the physical layer, transport layer, DDSN service layer, and the application layer.

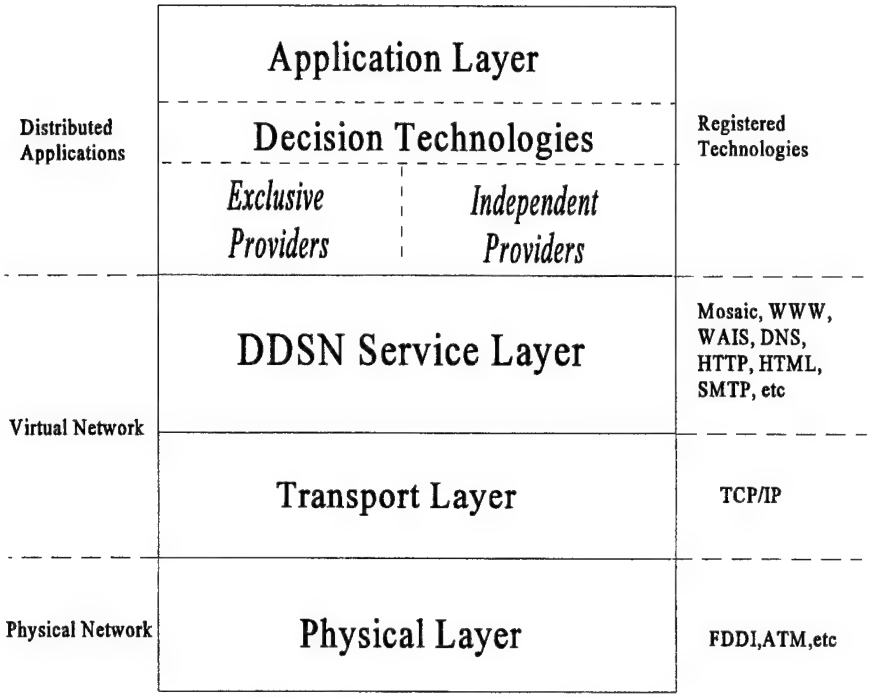

Figure 4. DDSN Reference Model

(1) *Physical Layer*. Consists of the communication lines required to connect to the network. This will be the choice of the consumer and provider and will vary according to availability of services.

(2) *Transport Layer*. Communication software which allows for communication functionality. Commonly called TCP/IP stack or DoD protocol stack.

(3) *DDSN Service Layer*. This layer contains users defined client software which allows access to the DDSS. The user chooses this software, but must conform to specific standards of the DDSS. An example would be a WWW browser. A user can use the browser of his choice if it is HTML 2.0 acquiescent.

(4) *Application Layer*. This layer contains all exclusive and independent decision technologies previously registered and available for use on the DDSN.

b. Functional Standards

DDSN functionality is currently based on the technical services available on the WWW. Table 1 identifies the recommended or de-facto standards for each of the technical services to achieve the following functions of the DDSS.

(1) *User Registration*. The user establishes an account with the network by providing pertinent information about their self or the technology they are registering.

(2) *Discovery and Search*. A mechanism to search for and learn about a decision technology.

(3) *Data Transfer*. The transparent transfer of data between consumer and provider, provider and user, and technology and technology.

(4) *Execution of Applications*. This function invokes execution of an application.

(5) *Support Functions*. All additional functions required to support users of the network. These functions would include such things as: On-line help services, reports, validation messages, and all management functions.

C. DDSN INFRASTRUCTURE

The DDSN infrastructure is comprised really of three separate infrastructures (consumers, providers, DDSS) which a fourth infrastructure (communication) unites. The absence of any one of these infrastructures will desolate the DDSN concept. In developing the DDSN infrastructure, discussing connectivity, hardware, software, and personnel requirements introduces the requirements of each infrastructure in general terms. A specific infrastructure will depend on the stage of development, established performance measures, amount of usage, types of data transfers, and known interdependicies between specific resources. More emphasis is placed on the DDSS infrastructure as it is the main entity of the DDSN.

		Functional Services				
Technical Service	Standard	Registration	Search	Data Xfer	Execution	Support
Communications	TCP/UDP/IP	X	X	X	X	X
	SMTP	X		X		X
	X.400	X		X		X
	X.500	X	X			
	Telnet				X	
	FTP			X		X
	DNS	X	X			X
	HTTP	X	X	X		X
	URL	X			X	X
	MMTP			X		X
	LISTSERVE					X
Database	ANSI		X			X
	SQL		X			X
	ISO RDA		X			X
Data Interchange	H.260			X		X
	SGML			X		
	HTML	X		X		
	VRML			X		
System Management	SNMP	X	X	X	X	X
	CMIP	X	X	X	X	X
Security	CIPS	X	X	X	X	X
	CRC-16	X	X	X	X	X
	CRC-32	X	X	X	X	X
	DES	X	X	X	X	X
	DSS	X	X	X	X	X
	JPSC	X	X	X	X	X
	MD1-5	X	X	X	X	X
	RSA	X	X	X	X	X
	SDNS	X	X	X	X	X
	SKIPJACK	X	X	X	X	X

Table 1. Functional and Technical Standards Cross Referenced

1. DDSN Communication Network Infrastructure

A network infrastructure capable of dealing with the amount and type of data envisioned to seamlessly integrate all simulation and modeling technologies does not currently exist. The Defense Simulation Internet (DSI) program is accelerating commercial development of the technologies needed by the simulation community for distributed work environments. "The ultimate goal is deployment of a gigabit network that will be inter-operable with commercial, optical and secure wireless networks." (ARPA, 1995) Use of the DSI or a comparable network is required to use the DDSN as a global network.

2. Consumer Infrastructure

Three areas of concern for the consumer's infrastructure exist: access to the network, computer platform, and required software.

a. Network Access

The type and speed of a network access are dependent on each consumer's individual requirement. ISDN and ATM technology are presently increasing the bandwidth availability to the end user. Internet dial-in connections are presently available at 14.4 or 28.8 Kbps. Consumers with ISDN presently connect to the Internet at 56 or 128 Kbps. It is projected that by the year 2004, Internet providers will provide T1 carriers to the home for about the same price of a modem connection today. (Robinson, 1995)

b. Hardware

An independent variable to the DDSN. Hardware used is dependent on the user requirements.

c. Software

The only required software is TCP/IP stack software and a WWW browser client which combine to make a common user interface. The consumer has choice in which TCP/IP stack and WWW browsers they choose to use. Additional TCP/IP software applications such as an E-mail client and FTP client are useful to the user. These applications are again the choice of the end user.

3. Provider Infrastructure

The provider has the same requirements for network access, but has additional requirements in hardware, software, and personnel. A service provider must provide an infrastructure which provides a service to consumers which are useful, reliable, and secure.

a. Hardware and Software

Providers of decision technologies will have freedom of choice in the hardware and software required to provide the processing of the decision technology and the transfer mechanism to support the transfer of input and output data. The type of technology and the interface requirements of the application will drive the software and hardware requirements for the provider.

Hardware and software requirements will be much less for independent providers since the provider's HTTP server can accomplish the transfer of data. The provider must provide the hardware and software to run an HTTP server and the decision technology application. CGI scripts accomplish the interface between the HTTP server and the decision technology back end process. Additional support functions such as: secure storage and transfer of data by files, and transferring output data back to the consumer will require additional server software and will be dependent on the provider's interface requirements. These additional requirements are independent to the DDSN and are dependent on the provider's preferences in providing the service.

b. Personnel

The provider is responsible for the functioning of the information system which provides the decision technology. Programmers, technicians, support personnel are the responsibilities of the provider.

4. DDSS Infrastructure

A Structured Analysis and Design Technique (SADT) model better known as an IDEF 0 model was developed to understand the activities and interaction of activities of the DDSS better. Appendix B illustrates the IDEF0 model of the DDSS activity "Provide

Decision Support Technologies." A functional prototype DDSS, named "DecisionNet"[3] was developed to compare and contrast different design options and to gain understanding of the total DDSS concept. (King, 1995)

a. DDSS Connectivity

The DDSS entry gateway needs to have a direct connection to the global communication network. A high volume of data is sent to and from the DDSS by the consumers and the decision technologies. A large pipe will be required to provide reasonable response time to the consumers.

b. DDSS Information System

The DDSS can be viewed as a business process consisting of an information system consisting of a variety of hardware, software, and personnel which will provide all required functionalities to users of the DDSN. Therefore, the activities and interaction of activities within the DDSS will heavily influence the DDSS infrastructure. Modeling of the DDSS identified three main activities, which will prominently influence the infrastructure of the DDSS: registration of users, validation of technologies, and providing an interface for the technology.

(1) DDSS Hardware. The current DDSS prototype uses a Macintosh P7100 as an entry HTTP server which we have tasked with serving DDSN introductory information and maintaining user statistics. A UNIX SPARC 2 is called to do all login functions, forms processing, search mechanisms, E-mail functions and all other back end processing. This configuration demonstrates that a distributed server configuration using a variety of hardware could support the DDSS. However, this is probably an impractical solution due to hardware and software maintenance issues. A UNIX-BASED commerce server (SPARC 20) with all server software installed will be sufficient as an initial gateway server. All back end processing will be supported via additional platforms as required. The determining factors in selecting the hardware configuration will be based on:

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[3]"DecisionNet" is a WWW based functional prototype, which allows access to a distributed network of modeling and decision support systems over the Internet. DecisionNet" is available for use at URL: http://dNet.as.nps.navy.mil/dNethome.html.

performance measures, required processing speeds, number of simultaneous users, security requirements, level of distributed computing environment, ease of maintainability, and cost of service and support.

(2) *DDSS Software*. Universities have built and distributed most of the server software used in the development of the prototype as free unsupported freeware. The software is not of production quality and is consistently receiving configuration upgrades. Freeware is appropriate in establishing proof of concept, but the DDSS will require an established and supported server software package. The following server applications are required at this time: DNS, FTP, HTTP, SMTP, Telnet. Additional Software applications such as NNTP, MMTP, ListServe, DBMS, DDSS middleware will be required to support back end processes and support functions of the DDSS.

(3) *DDSS Personnel*. The personnel required to support the DDSS will be largely dependent on the technical staff required to support the information system. Network managers and system analysts will be required to maintain a 24-hour information system. Additional personnel classified as "Decision Support Specialist" are tasked with classifying, validation, and verification of technologies registered with the DDSS and later as help desk consultants. Programmers will be needed to develop technology specific interfaces and middle-ware required for automated technology registration and data translations. Personnel required to support the DDSS should decrease as functions are automated and different stages of development are realized. Additional help desk personnel will be required to help in setup, execution, and monitoring use of applications during the middle stages of development.

D. SUMMARY

The DDSN architecture is a very high level architecture which will continue to evolve over the project development stages. This architecture is based on the present architecture of the WWW, which being in an infancy state is also evolving. Further research, enabling technologies, and development of the DDSS will influence the architecture of the DDSN.

It is evident from the initial architecture that further research and development will be centered around the DDSS architecture and infrastructure. However, we must also establish a market for distributed decision support technologies. We must identify enterprises and functional areas that need this type of technology and obtain their requirements. Consumers' willingness to divulge corporate or personal data to a distant site for processing must be analyzed. These type of issues concerning the providers and consumers also should be considered research challenges. Without providers and consumers, a DDSN does not exist.

This chapter provides an initial architecture framework that documents the ideas behind the DDSN concept. It establishes a road map which researchers and developers can follow to continue research and development of the DDSN ideas. Since the DDSN concept was developed in an academic environment the initial architecture is based on ideas of the initial project team and does not reflect requirements established by a single customer requiring this service.

V. MODELING AND SIMULATION IN THE DOD

A. INTRODUCTION

Reductions in force structure and annual operating expenses have placed more emphasis on the use of models and simulations to maximize use of available resources. DoD believes that Modeling and Simulation (M&S) can improve military capability and decision making in four areas: readiness, modernization, force structure, and sustainability. The DoD M&S vision is to support DoD components in a variety of functional areas by developing, maintaining, and distributing a wide range of models and simulations to support their objectives. Figure 5 illustrates the range of the vision for M&S in the DoD. (DoD, 1994) (DoD, 1995)

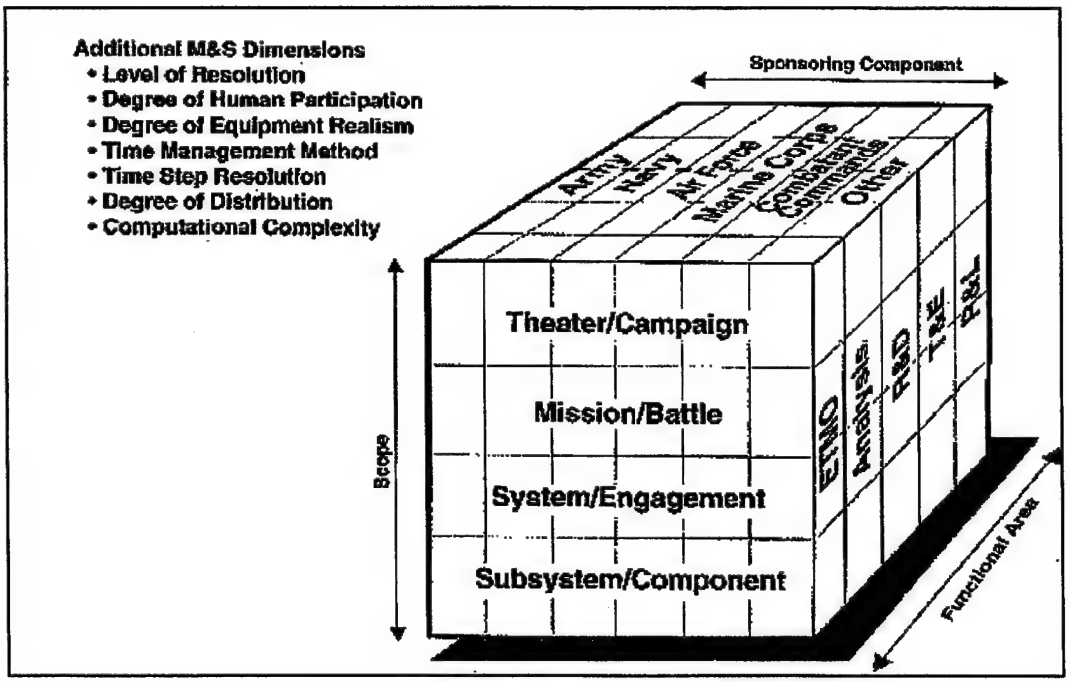

Figure 5. Range of M&S in DoD, DoD Master Plan, DoD 5000.59Paa

The Defense Modeling and Simulation Office (DMSO) was established to coordinate policy, establish interoperability standards and protocols, promote simulation in the military

services, and to establish guidelines for coordinating simulation, war gaming, and training. (U.S. Senate, 1990) The DOD Executive Council for Modeling and Simulations (EXCIMS) was established to provide the Under Secretary of Defense (Acquisition & Technology) (USD (A&T)) a mechanism to establish and implement DoD policy, initiatives, standards, and capabilities to enhance (M&S) in the DoD. EXCIMS is comprised of DoD Component representatives and is chaired by the Director, Defense Research and Engineering (DDR&E). (DoD, 1994) DoD has the management resources in place and must now bring their vision to reality.

This chapter discusses objectives of the DoD M&S Master Plan that are relevant to the concepts of the DDSN, identifies ongoing DoD M&S and C4I projects that are similar and/or related to the DDSN concept, and discusses how the DDSN concept could be used to support DoD functional areas with decision support technologies.

B. DOD M&S MASTER PLAN OBJECTIVES

The DoD M&S Master Plan establishes long term objectives for M&S within the DoD. (DoD, 1995) The plan is broken down into six objective areas as illustrated in Figure 6. Objective one, five, and six of the master plan parallel the concept of the DDSN. DoD's emphasis is on the use of simulations for decision support, while the DDSN emphasis is on analytical models. The common objectives are discussed below.

1. Common Technical Framework for Modeling and Simulation

DoD desires a common framework which will facilitate interoperability between models and simulations, integration of M&S with C4I systems, and increased usage and reuse of M&S. Their approach is to dictate a high level architecture and to standardize representations of data with which all DoD models and simulations will conform. While the methodology to obtain the objective is different, the goals are similar to that of the DDSN. The DDSN concept establishes a multi-dimensional taxonomy of objects which are based on the inputs and outputs of the application. The provider declares input and output data formats in a "Parameterized" Format Description Language (PFDL) and is translated by

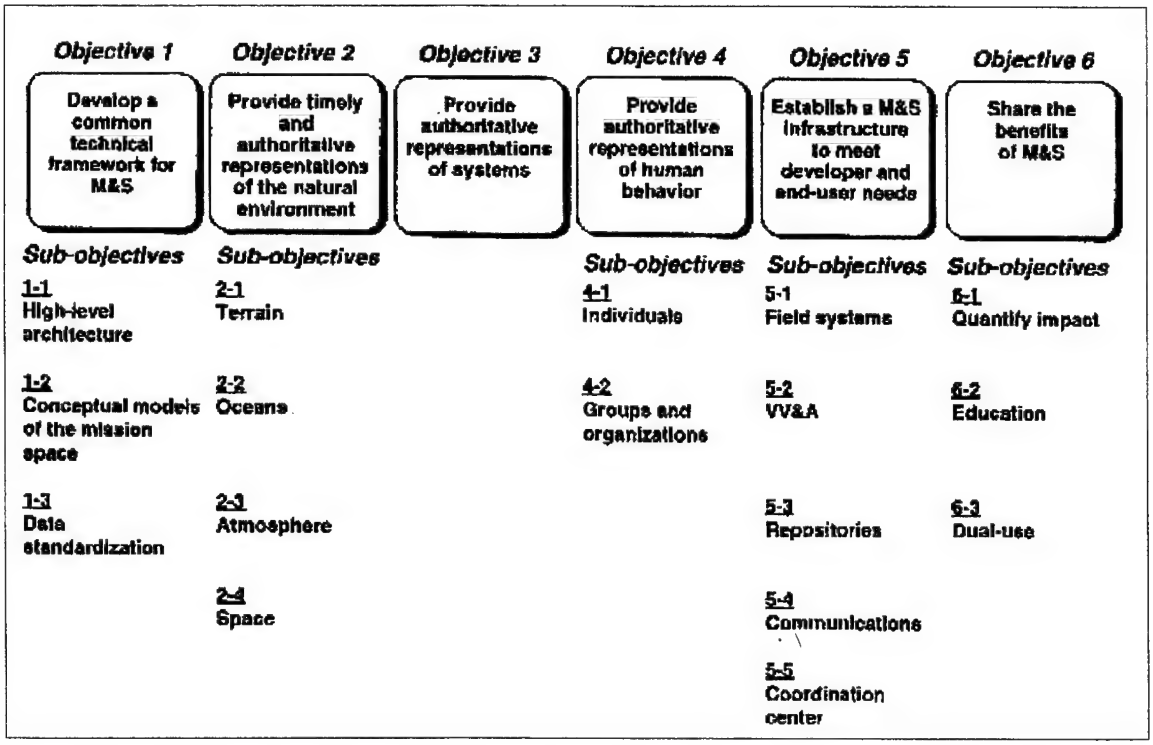

Figure 6. DoD Modeling and Simulation Objectives; DoD Master Plan DOD 5000.59Paa

agents of the DDSS. Format conversions are done as required to allow for transfer of user data and interoperability between applications.

2. Establish a M&S Infrastructure to Meet Developer and User Needs

Goals of the DoD M&S infrastructure are also similar to that of the DDSN. The DoD infrastructure is broken into five components defined as the following sub-objectives:

a. Field M&S Systems in Adequate Numbers to Meet End User Needs

A DoD Inspectors General (IG) inspection conducted in March of 1993 substantiated that the DoD lacked the ability to effectively and efficiently use models and simulations. One of the major findings was that applications were developed as stand alone models with no reuse capability; another was that there were redundant investments in similar systems. An estimated 800 million dollars could have been saved in FY93 if an effort to consolidate systems would have occurred. (Mercer, et al., 1994)

In an effort to reduce redundancy, DoD plans to identify user requirements for M&S within five functional areas: Education, Training, and Military Operations (ETMO), Analysis, Research and Development (R&D), Test and Evaluation (T&E), Projects and Logistics (P&L). Once user requirements are identified, DoD will plan and program the fielding and interconnection of the necessary models and simulations to support the needs of the entire DoD. Unused M&S systems will then be phased out of the system.

Identifying requirements for a single user is a difficult task, identifying requirements of multiple users over five different functional areas seems impossible. It could be argued that this is an unrealistic objective due to continually changing requirements. The DDSN concept takes somewhat of a reversed position on achieving this objective. Instead of reducing the applications available, all M&S resources would be made available, giving the user more flexibility in choosing and using the tools to support the mission.

b. Validation, Verification, and Accreditation (VV&A)

DoD realizes that VV&A and Verification, Validation, and Certification (VV&C) is required to achieve confidence in the use of M&S by the user community. Standards, policies, and procedures need to be developed to achieve VV&A and VV&C. The DDSN concept shares the same concern for VV&A of technologies made available on the DDSN. VV&A is initially the responsibility of the provider of the technology, however the DDSN will need a process to verify the providers VV&A.

c. Repositories

To enhance development, use, and increase awareness of models and simulations, DoD is developing a resource library. An Interim M&S Resource Library (IMSRR) is presently operational with a WWW interface at Fort Huachuca.[4] The goal of this library is to provide developers and users of M&S with "timely, verified, and validated data, metadata, algorithms, models, simulations, and tools." This repository allows users to learn about a technology by reviewing background information (e.g., data source, VV&A/C

[4]Available at URL: http://huachuca-jdbe.army.mil; hosted by Joint Data Base Elements for Modeling & Simulation (JDBE).

history, algorithms used, developer). The user can then decide if the technology is useful and can retrieve the technology for use. This type of library may support a developer, but will probably not be used by an average user of M&S. The arguments for developing a DDSN established in Chapter II support this position. An average user wants to use a technology and does not want to worry about the configuration and management of it.

The DDSN repository is similar, but is described as an ***executable*** electronic library of decision technologies. The DDSN repository could be used as both a reuse and use library. This would benefit both the developer and the user of M&S. The developer could review the background material and also execute the technology to determine if the functionality of the technology met the requirements. The user would access, provide data, and use the technology as required, without obtaining the technology software.

Another problem with the IMSRR and other catalogs of M&S technologies is the storage of metadata concerning the technology. Once the information is provided, it is immediately outdated. In today's distributed environment this information should be dynamic. When a model or simulation technology is modified, all repositories should also reflect that change. The IMSRR and M&S catalogs require background information be managed by the facilitator of the repository, not the developer of the technology. Because technologies are always changing and improving, the developer should be made responsible for this information.

d. Communications

DoD presently has the Defense Simulation Internet (DSI) in place and believes that by increasing reliability and bandwidth that DSI can be transitioned into an operational service for the distribution of models and simulations. The current defense information infrastructure, commercial services, and radio frequency communications will be utilized to link DSI with C4I systems. This will allow M&S support to any DoD user, anytime, anywhere. The DDSN has the same goal; decision support to any user, anytime, anywhere. The same type of communication requirements exist for the implementation of the DDSN.

e. Coordination Center

The DoD is establishing a M&S Coordination Center (MSCC). This center will provide support to all users (Cincs, Services, Agencies, Project Managers) of all functional areas. The MSCC will be responsible for coordinating, advising, and establishing use of world-wide distributed simulation capabilities. Due to the size and complexity of this M&S network, human assistance will be required to coordinate usage, assist users, and to make M&S systems available.

The DDSN also requires an organization of this type, but of a much smaller scale. By using software agents it is envisioned that the resources required to provide some of these functions can be automated. The best example of this is defined by the level three configuration of the DDSS. At level three the user merely states the problem and the DDSS would automatically identify the best technology to assist the user.

3. Share the Benefits of M&S

This objective within the DDSN concept is to allow a diverse set of users access to a variety of decision support technologies with minimal overhead. However, DoD defines this objective by three sub-objectives:

a. Quantify the Impacts of M&S

In an attempt to assess the value of M&S, DoD desires to establish quantitative measures which illustrate the utility of M&S within functional areas. While this is not a functional goal, it serves to justify and educate agencies that are ignorant of M&S capabilities.

b. Education of M&S Users

New users of M&S will require education and training in establishing and using M&S resources. DoD plans to conduct seminars and workshops to expand user awareness across the M&S community. Since the DDSN is WWW based, the training, education and dissemination of information is supplementary to the system. The DDSN also allows for a serendipity learning environment; the user may have no idea that an application exist, but by browsing the repository may find a suitable technology to support a known or future requirement.

c. Technology Transfer with Other Agencies

DoD desires to stimulate technology transfer of M&S between other government agencies, private industry, universities, and other nations. Traditional methods such as demonstrations and meetings are being planned to accomplish this objective. The transfer of technology is also built into the DDSN. Developers can learn about and test an application maintained in the executable repository of the DDSS. If additional information is required about a technology, developers can go off line and discuss relevant issues.

C. DOD M&S AND C4I PROJECTS

There are a few projects presently being researched and developed within the DoD which demonstrates the integration of M&S with C4I. A few of these are discussed below.

1. Distributed Interactive Simulation (DIS)/Advanced Distributed Simulation (ADS)

Originally sponsored by Defense Advanced Research Projects Agency (DARPA) and known as the SIMNET (SIMulation NETwork) program, this concept has evolved into DIS, ADS, and now, High Level Architecture (HLA). DIS is the infrastructure which implements the concepts of ADS. The ADS concept is to synthetically create large environments so users can interact in real-time simulations. The HLA architecture creates a framework for developers and policy makers to address simulation design and implementation issues.

The initial focus of this technology has been in training, however DIS/ADS is seen as a tool for evaluating new concepts in a variety of military functional areas. The Defense Science Board (DSB) believes that this technology will also aid in research and development, prototyping of systems and testing of weapon systems in synthetic environments. These environments or virtual worlds are linked electronically to give a shared representation of space. Linkage to other sites allows real time interaction, with man-in-the-loop affecting the outcome. The two distinct characteristics of this technology are that the simulations are physically separated and they must be electronically connected to allow for a common picture of the environment space. This allows all nodes to act, interact, influence and respond within the same battle space. (Mercer, et al., 1994)

2. Common Operational Modeling Planning and Simulation Strategy (COMPASS)

The goal of COMPASS is to "bring modeling and simulation services and collaborative planning tools to C4I." A common messaging environment using middleware is used to extend DIS protocols from modeling and simulation to C4I systems. COMPASS provides an Application Program Interface (API) which acts as a presentation layer and translation layer between legacy planning systems. This allows for the use of proven planning systems to be interfaced using commercial distributed computing applications. The Distributed Collaborative Planning (DCP) applications (whiteboard, video conferencing, shared overlay management) allow planners to collaborate on plan development. The modeling and simulation tools allow all planners to preview composite mission and simulated mission rehearsals. This program leverages current investments (legacy planning systems), allows collaboration between geographically dispersed planners, and allows for a preview of the plan developed. (Nayfack, 1995)

3. Joint Task Force/Advanced Technical Demonstration (JTF/ATD)

The JTF is the crisis response team for the DoD and is required to respond to a variety of situations. The idea of the JTF/ATD is to provide the JTF Commander with the right tools to create plans, analyze courses of actions, communicate plans, and to enhance perception of the current situation. The JTF/ATD is an Advanced Research Projects Agency (ARPA) project which envisions "a mobile distributed network of graphic planning cells sharing a common reasoning infrastructure and architecture." (Kral, 1995) This environment would allow for concurrent assessment, plan generation, scheduling, and analysis processes between the Commander Joint Task Force (CJTF), CJTF components, and supporting Commander-in-Chiefs (CINCS). The architecture is based on a COE and shared object classes with flexibility in adapting to current needs by integrating new software modules. Flexibility is established by developing new software modules for different situations. A module may take between two person hours to a few person weeks to develop and integrate with the system. (Erman, et al., 1994)

D. DOD AND THE DDSN CONCEPT

1. Overview

As identified by the discussion of the C4I/M&S projects, it is evident that the DoD is moving towards a proprietary system to integrate M&S with C4I. Developing a proprietary system will allow for an efficient and reliable method to interface required M&S applications. A HLA must be established and maintained that developers and policy makers must conform to. Developers must conform to these standards and data conventions to guarantee interoperability and information transfer between applications. New M&S applications, will be developed easily as they will use standardized information definitions. Preferred stove pipe applications will be re-engineered or middleware will be developed to allow for their use in this architecture.

The DDSN concept allows for applications to be built independent of a standardized architecture and allows for transfer of information by allowing middleware to translate the input and output data. While it can be argued that the translation of middleware is maintenance intensive and promotes building of stove pipe applications, new technology is envisioned that will dispute this argument. Software agents are becoming popular in automating processes that usually require extensive interface and communication. By developing these software agents to automatically register independent technologies and build required interfaces, the maintenance of such applications should be reduced.

2. DDSN Areas of Use in the DoD

It is the authors opinion that the DDSN is not a concept that would replace a proprietary DoD M&S distributed system, but one that would support or complement it. The proprietary system should allow a method to access and use other M&S resources to assist in the decision making process in the event a tool or data is not available. Under the DDSN concept, a large repository of decision technologies from universities, research institutions, industry, and individuals would be made available to the DoD for use as required. Military schools, military analyst, acquisition professionals, and individuals could all benefit by having access to a repository of such technologies. A discussion on how these areas could benefit from the DDSN concept is provided.

a. Military Schools

Students at graduate, mid-level, and upper level schools could share technologies that were developed by students of other schools and curriculums. A lot of time is wasted developing models and algorithms which have previously been developed to support another students or professors work. A DDSN would increase awareness and use of existing technologies from all Colleges and Universities abroad. These technologies could also serve as starting points for re-engineering or development of new applications.

b. Acquisition Professionals

The use of Models and Simulations within the acquisition process presently supports all communities involved in the development, design, manufacturing, and testing of the system being acquired. A variety of models, simulations and supporting data is required to conduct mission area assessments, mission needs analysis, cost and operational effectiveness, measures of effectiveness, and measures of performance. The list of analysis tools available to support a program manager is quite extensive. The data sets, models and analytical tools required by all acquisition activities could be provided for use in a distributed environment as outlined by the DDSN architecture. All activities could share the same supporting data and analytical tools from the requirements to the implementation stages of the project life cycle. If supporting data was changed, it would only have to be changed at one location, reducing the chance of errors in analysis. This would also promote reuse by making applications available for future projects.

c. Military Analyst

The complexity of the modern battlefield and the amount of information available to the military commander has increased reliance on supporting staff and military analyst. Analytical support is being provided to field commanders by establishing help desk or anchor desk in specific functional areas (e.g., logistics, intelligence, meteorology, manpower). These help desk are located in the rear areas and are manned by professional analyst and contain analytical tools to support the commanders decision making process. High speed communications are used to transmit unique data and request for analytical

support from the commander, the analyst will then use a variety of tools to compare contrast and give feedback on the request.

Today's military performs a variety of missions which are categorized as "Operations Other Than War." Commanders are often confronted with scenarios that current military doctrine and tactics do not address. Analytical tools and information unique to these new missions may also not be available. The DDSN concept would allow analyst in a variety of disciplines to connect to a repository of decision technologies outside of DoD that may support these operations. In addition to the predefined tools that have been established to support established doctrine and tactics, a new dimension of support applications can be made available to combatant commanders through help desk or accessed directly by the Commander in the field.

d. Individuals

Personnel are consistently identified as the most important resource in the military services. Many support services, such as relocation specialist, family support, financial support and retirement services are required to achieve and maintain a high degree of morale by service members. These services may or may not be used by service members, but are made available, in case they do. It is believed that DoD personnel could also benefit from having access to decision technologies which assist them in making career decisions as well as personal decisions that influence their everyday life. Some of the services that are presently presented by clinics and seminars could be made available using the WWW and DDSN technology. This would allow personnel to obtain information and to use decision support services at their own convenience. This would reduce some of the overhead presently associated with these type of support activities.

There are probably many other situations in which the DDSN concept could be employed within the DoD. Basically, any organization that requires assistance in making decisions could benefit from this technology.

E. CONCLUSIONS

The DoD has generated a vision to effectively and efficiently use M&S to support a conglomerate of mission requirements. The integration of M&S to C4I will allow decision makers in a variety of functional areas to assess units performance and capabilities, develop and evaluate operational plans, and conduct what-if analysis in academic, training, and operational environments to achieve this vision, DOD must:

- Develop a HLA architecture which will mandate common standards and conventions to be used in future M&S system and application development.
- Re-engineer existing preferred stove pipe systems that are considered mission essential to function within the new architecture.
- Identify requirements of functional areas to be supported.
- Develop and maintain applications required to support all functional areas.
- Develop and maintain the technical architecture and infrastructure to support the integration of M&S with C4I.

This architecture will allow chosen sites the use of selected and predetermined M&S applications to support missions identified by functional user requirements. While the architecture provides a mechanism to share M&S resources, it also creates a high level of system and application maintenance overhead. A MSCC will be required to assist users and coordinate usage. Additionally, all sites will be required to maintain a suite of software that is required for the transfer of information and to achieve interoperability between applications.

While the goals of the DoD vision and the concepts of a DDSN are the same, the target environment is different. DoD's vision provides a designated set of users within functional areas, a predetermined set of models and simulations. [The DDSN idea allows all users of a common network access to an undetermined amount of decision technologies; limited by availability only]. Use of the DoD M&S network would require users to have

access to a designated platform which is configured for use of the M&S network. The DDSN concept allows any user with a personal computer to become an instance of an application running on a super computer with limited software requirements.

The dynamic scenarios which components of the DoD support will require flexibility in the type of applications made available. The COE envisioned will provide applications to support decision makers with well defined and understood problem situations. A mechanism, such as that proposed by the JTF/ATD will be required to allow for the expedient development and interface of modules to assist decision makers in diverse and unknown situations. The DDSN architecture could compliment the simulations and models available within the M&S COE; allowing immediate access and use of models and simulations that may only be used sporadically, under unique situations.

VI. CONCLUSIONS

A. THESIS SUMMARY

This thesis introduced a new concept for integrating decision support technologies with global computer networks. The main objective of this concept is to provide decision support technologies to users of a global heterogeneous network with minimal standards and conventions dictated. The architecture and infrastructure of the DDSN provides documentation for further research, development, and implementation of this concept. The architecture and infrastructure identified in this thesis is based on the ideas of the WWW and will continue to evolve.

The DoD also realizes that the integration of M&S with computer networks will provide for better use of M&S resources. They envision integrating M&S with C4I to increase availability, shareability, and reuse of M&S applications between a variety of functional areas. Their infrastructure to achieve this is based on a COE and mandating standards and conventions in the development of M&S applications. This infrastructure will guarantee interoperability between applications, but will restrict access to those applications identified by functional area requirements. The DDSN infrastructure can augment the DoD infrastructure by allowing users to use decision technologies developed outside of the COE. This will allow users to access technologies that may only be required for a specific situation.

B. AREAS OF FURTHER RESEARCH

The general nature of this thesis has resulted in identifying a variety of topics of which will require further research. Further research of the DDSN concept falls into three general categories: further development of the DDSS, identifying or developing applications to demonstrate the functionalities of the architecture, and developing a plan for managing the DDSN infrastructure.

1. Future Development of the DDSS

Decision Net, the DDSS prototype, has proven the ability to execute independent technologies remotely using WWW technology. The next development stage of the DDSS

will allow for automatic registration and interactivity between exclusive applications. Before this software can be developed, a taxonomy of decision technologies needs to be established and an algorithm to classify decision technologies must be created. A determinant factor in user satisfaction of the DDSN will be the ability to find the correct application for a given situation. The taxonomy and classification mechanism will be essential in developing an intelligent search agent to locate applications best suited to support a users problem definition.

The development of the middleware which provides for the translation of inputs and outputs to achieve interoperability is based on theory and a proof of concept is required. Further research must prove PFDL and address the limitations of the language. Intelligent software agents need to be developed which will allow for the expedient translation of data to the new data type. Methods to store, identify, translate, and deliver these data objects must be developed and implemented.

2. Developing Applications to Demonstrate DDSN Potential

Users of the DDSN will require confidence of the applications made available, providers must also realize the benefits of this technology before they will want to register their technologies. An assortment of killer applications, which illustrates the benefits to all users and capabilities of the network needs to be identified and implemented. These applications should be real world applications that can be used within a functional area. A possible area of interest may be within command and control.

3. Develop a Management Plan for the DDSN and the DDSS Infrastructure

The management facet of the DDSN needs to be researched since the DDSN can be considered as a service oriented business. As such, a management plan to ensure satisfaction of service is required. The management plan should address all legal, financial, and regulatory concerns of the system, identify performance measures, optimal system configurations to meet those performance measures, and quality control methods employed to assure satisfaction.

In developing the management plan, potential barriers will need to be addressed and resolved. An example is the issue of software licensing of distributed applications. Will new

legislation need to be introduced to allow for multiple users to access and use a software application running on the software owners machine? Charge back mechanisms must also be identified and a method to monitor usage, initiate billing, and receipt of payment from users must be established. Additionally the system must provide for a certain degree of performance standards (security, reliability, and availability) to all users of the network. Server and network configuration management issues need to be addressed, metrics to measure performance standards identified, and methods to provide security of corporate data established.

C. CONCLUSIONS

This thesis established proof of concept for the distribution of decision support technologies to users of a global network. The initial architecture and proposed infra-structure identifies the DDSS as the link pin of the DDSN idea. The DDSS provides the majority of functions which allow for access, execution, and interoperability between all entities of the network. The DDSN concept is dependent heavily on the technical development of the DDSS, however it is also dependent on developing an electronic market of decision support services. Consumers and providers of decision technologies must want to use the services of this market. Government interest in NII, and the expodential growth of the WWW suggest that electronic commerce is the wave of the future. The DDSN concept is one way in which the decision sciences can ride this wave.

The initial architecture develops the DDSN concept as a global resource, used by all who have access to the Internet, however, it is felt that the concept is also suitable at an enterprise level. A computer integrated enterprise is based on the integration of information and decision logic to achieve functional synergies. A DDSN would provide access to the same corporate data as well as decision aides required to process this information. Decision makers could use the same decision aides which would enhance decision logic. Each corporation would maintain a DDSS which would also allow for accountability, user availability, and reduced maintenance cost of decision technologies for the corporation.

The DoD evidently expects the use of M&S to increase readiness and reduce wasted assets in the DoD. DoD has traditionally used simulations in war gaming, virtual weapon system trainers, and live simulations in a training environment. Models and decision support systems have traditionally been developed to support specific requirements. DoD is in the process of building a M&S network which will meet the known requirements of five functional areas and allow for interaction between all. It is felt that the DDSN idea can augment this network by making additional technologies available to all users of DoD.

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GLOSSARY (DEFINITIONS)

Architecture: The structure of components in a system, their inter-relationships, and principles and guidelines governing their design and development over time.

Consumer: Any person or organization who is in the market for computational decision support services.

Distributed Decision Support Network (DDSN): A computer network which allows for the distribution of decision support applications over a global network; a DDSN consist of a computer network, providers of decision technologies, consumers of decision technologies, and the (DDSS).

Distributed Decision Support Server (DDSS): Provides the mechanisms which allow users to register, search for, connect to, and execute a decision technology. The DDSS is comprised of hardware, software, and the personnel assets which allows for the functionality of the DDSN.

Infrastructure: Resources used to achieve desired functionalities of a system (Personnel, hardware, software, communications).

Network: Allows for the physical transfer of data and the seamless interaction between different types of platforms.

Provider: Organizations, developers and/or individuals who desire their decision technology to be executable over the network.

APPENDIX A. ENABLING TECHNOLOGIES

A variety of technologies will have significant impact on the development of the DDSN concept. This appendix identifies technologies by discussing general trends and briefly discussing each technology.

A. TRENDS

The use and performance of information systems technologies have increased by 30-50% percent per annum over the past two decades. If this continues more than 1000 MIPS and hundreds of megabytes of memory in workstations, supported by billions of bytes of local storage will be available at the same cost of today's high-end workstations.

Communications bandwidth capacity exceeding 1+ Gbps is available today. This will give the consumer the bandwidth on demand required for high resolution multimedia.

Information search and retrieval capabilities available in client/server environments are allowing consumers to find the information available over the global networks. The increase in demand from users for new tools to expedite information retrieval will be eventually led to interconnectivity and interoperability of data and software applications. Distributive Collaborative Planning tools will be the norms on most desktop environments. This will allow for interaction for planning and telecommunications.

Mass storage capacities will continue to increase with decreased cost. Today, hard disk drive mass storage can be purchased at $1 per megabyte (MB). New storage technologies will emerge, lowering cost.

Multi-level security (MLS.) continues to be a serious topic and will require further research. Some organizations will have accredited MLS systems. A US Government-wide MLS policy does not exist and will probably not be developed for some time. Providing security of information will be a necessity for service providers of a global network.

The use of Object-Oriented Technologies (OOT) will expand into software development, operating systems, and database management.

The use of Virtual Reality is becoming popular in developing user interfaces and modeling techniques. Interactive simulations allow for geographically distributed users to interface and to influence the environment for which they are acting. This technology is available presently to high end computing systems and require dedicated networks. The Virtual Reality Modeling Language (VRML) vision is to bring interactive 3D to the Internet

via the WWW. This may influence the use of 3D models and simulations at a lower level of computing.

B. COMMUNICATIONS

Significant advances in networking and long-haul communications technologies are expected. Local Area Networks (LANs), such as the 10 Megabits per second (Mbps) Institute of Electrical and Electronics Engineers (IEEE) 802.3 Ethernet and 16 Mbps IEEE 802.5 token ring are commodity items available worldwide today. Public packet-switched Wide Area Networks (WANs) are operated in all industrialized countries. Large private networks in both the Government and commercial sectors are starting to use T1 (1.544 Mbps) and T3 (45 Mbps) transmission circuits. Asynchronous Transfer Mode (ATM), and Synchronous Optical Network (SONET) will dominate both Government and public-sector communications networks.

C. INFORMATION SYSTEMS

Information systems are encomposing more users. Workstations and personal computers are now interconnected allowing access to better resources and sharing of information. Client/Server technology and the Distributed Computing Environment (DCE) are allowing for the distribution of data, display, and functional processing throughout the network. Client server technology is currently being implemented, while DCE is still immature and in the experimental stages.

D. SECURITY

Several security technologies can be used to provide information security services such as data confidentiality, data integrity, access control, identification and authentication, nonrepudiation, and availability. Service providers will have to guarantee security of consumers data if electronic commerce will be accepted by the populous general. MLS will be required to achieve true interoperability between users with different security classifications; both data and information systems. Labeling, storage, and processing of data, write up technologies, and separation of environments make MLS a hard nut to crack.

E. OBJECT-ORIENTED TECHNOLOGIES

Object-oriented technologies (OOT) are emerging as a group of technologies that will allow information systems to be reusable, interoperable, and portable. The technology is demonstrating significant cost and time savings in commercial and government trials, including military. The emerging work from these efforts form the basis for the full life cycle of software; they support system development and data management. Areas of OOT that will probably effect the development of the DDSN concept are : object-oriented analysis and

design (OOA/OOD), object-oriented operating systems (OOOs), object-oriented programming languages (OOPLs), object-oriented database management systems (OODBMSs), and Object Management.

F. COMPRESSION TECHNIQUES

Technologies exist to compress digital images and video to a fraction of their original size for storage and transmission. Methods that achieve high compression ratios remove some data to achieve smaller data files. The use of simulations for playback or possibly interactive simulations will require large compression ratios. The Virtual Reality Modeling Language (VRML) presently uses compression technology to transmit 3D worlds to users of the Internet. The resolution required by the application and the user will determine the type of compression required. Some technologies are "lossy" because the decompressed images are reduced in size. Lossless methods also exist where data file size is reduced during compression but none of the data is lost when the file is decompressed.

G. VIRTUAL REALITY MODELING LANGUAGE

VRML is a draft specification for adding 3D data to the Internet via the WWW. The current vision is to allow for a 3D browser to search, travel and interact with major repositories of information on the WWW. This proposal would allow Virtual Reality (VR) environments to be incorporated into the World Wide Web, thereby allowing users to"walk" around and visualize actual environments. VRML is a logical markup language that will be used for non-proprietary platform independent VR. It is believed VR will become an increasingly important medium and will be accessible due to increases in bandwidth and high end computing assets availability. This mechanism would allow users to share VR models and possibly interactive simulations on a global basis from desk top computers. Presently, VRML technology allows a user to build a world with hyper text links embedded to allow a user to connect to another world or another information repository. This is a low end system which allows movement through cursor keys. This technology has great potential for global interactive 3D environments.

APPENDIX B. SADT/IDEF0 MODEL OF A DDSS

A. PREFACE

A Structured Analysis and Design Technique (SADT)[5] commonly called IDEF 0 was used to model the activities and the interrelations of these activities required to distribute decision support technologies. This model is nothing more than a tool to help the author better understand and describe the requirements and relationships of the processes of the Distributed Decision Support Server (DDSN). The system in focus for the model is the DDSS.

An IDEF 0 model has a single subject. The subject of this model is "Provide Distributed Decision Support Technologies." Obtaining the correct subject is critical in the development of the model. It must focus on understanding the system. The boundaries of the system, what is inside and what is outside the system, must be clearly defined. The subject must be bounded to concentrate attention on the system being described and avoid the introduction of external environmental entities.

An IDEF 0 model has one viewpoint or perspective. The viewpoint of this model is that of the system administrator of the DDSN. A viewpoint can be a person, place, or thing of the system in which if replaced, could watch the overall operation of the system. Different views will yield different descriptions of the system being modeled.

The IDEF 0 software BPWIN[6] was used to develop the top-down diagrams. The diagrams start with a general diagram and are decomposed into more specific diagrams which outline the activities of a specific system. The collections of these diagrams and the natural language obtained from user descriptions compose the IDEF 0 model. The diagrams use boxes, which represent functions or activities and arrows which represent interconnections between the boxes. The boxes are numbered alphanumerically and represent the origin and the path used in the development of the model. A-0 is the top level diagram commonly called the context diagram. A0 is the decomposition of the context diagram. This diagram will contain 3-6 boxes which will be labeled with a single numeral (1, 2, 3). When these boxes are decomposed, they will become the A1, A2, A3 diagrams. This process continues through the last level of the model. The arrows identify information or data needed to carry out the functions or activities. An arrow coming into a box from the

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[5]The explanation of the SADT/IDEF 0 business processing and enterprise modeling is summarized from Marcia, David A., and McGowen, Clement L., *IDEF 0/SADT Business Process and Enterprise Modeling*, Electic Solutions Corp, San Diego, 1993.

[6]BPWIN 1.50b is a beta version produced by Logic Works.

left, is input data, while an arrow coming out of a box on the right side is output data. An arrow coming from the top shows a control order while an arrow coming in from the bottom shows a physical resource or mechanism required to do a function.

Identifying inputs, outputs, controls, mechanisms and a brief description of the functioning will explain each box of the model of that activity. The purpose of explaining each box is to describe how each activity functions independently and the interaction required with other activities of the system.

B. NODE A-0: CONTEXT DIAGRAM OF PROVIDE DISTRIBUTED DECISION SUPPORT TECHNOLOGIES (Figure B-1)

Activity Number:	A-0
Activity Name:	PROVIDE DISTRIBUTED DECISION SUPPORT TECHNOLOGIES
Input Name:	Consumers Info, Decision Technology Info, Metadata Requirements, Providers Info
Output Name:	Billing, Distributed Decision Technology, Management Reports, Registration Information, Registration Verification
Control Name:	Legal, Protocols, Validation&Verification Criteria
Mechanism Name:	Information System, Personnel

Activity Definition: The Distributed Decision Support Network (DDSS) is the main focus of the system. The DDSS is a conglomerate of servers which interact to provide functionalities required to distribute decision technologies. The main server is a Hyper Text Transfer Protocol (HTTP) server which is called the Distributed Decision Support Server (DDSS). The DDSS will interact with other types of servers (SMTP, FTP, DBMS) to provide for registration, validation and interface of decision technologies to all users of the network. The protocols control the interface and functioning of these servers of the information system.

The providers, consumers, and the technologies interfaced to the DDSN are considered external entities of the system. The system requires a variety of information from these entities to provide for the user/system interface and the actual access and execution of decision technologies. This information is controlled by the metadata requirements established by the DDSN, legal obligations to protect private information established by the U.S. government, and Validation and Verification criteria established by the decision sciences to ensure the technology provides the support advertised.

The main output of this system is an interface to a "Distributed Decision Technology." The technology is physically outside of the system but the interface which allows for the technology to be accessed and executed is considered an output of the system. Other outputs are tools that are required for the management of the system. These include a variety

of reports, registration information, and billing or usage information. Registration verifications are sent to users of the system upon successful registration as a provider of a decision technology or a consumer of the system. At this time, the distribution of decision technologies is a semi-automated information system which requires personnel to accomplish validation and management activities. Some of these functions will be automated, however this model identifies the personnel required at this point in time.

C. ARROW DEFINITIONS

1. Inputs

Things such as data or information which is used or transformed by the activity. Arrows come into the activity from the right.

a. Providers Info

Information about the provider which is needed to register the provider with the DDSS.

b. Consumers Info

Information about the consumer which is required to register the consumer as a user of decision technologies.

c. Decision Technology Info

Information about the decision technology which is to be registered with the DDSS. Information will include the metadata, validation and verification criteria unique to the application, and all interface requirements.

d. User Request

Upon registration users (providers and consumers) will desire different services from the DDSS. These services will require the user to initiate a process or activity.

2. Outputs

Represent the things for which the activity has transformed or created. Arrows leave the activity from the right.

a. Management Reports

Reports used by the DDSS staff to identify users of the system and technologies available on the DDSS.

b. Registration Information

This is the users information which has been validated and is available within the DDSS databases.

c. Registration Verification

Notification to the user that the user registration process has been completed.

d. Distributed Decision Technology

A technology that has been successfully registered, validated, and interfaced for use by registered consumers of the DDSN.

e. User Statistics

Any and all information about the use of the DDSS.

3. Mechanisms

Represent the physical aspects of an activity or how activities are realized. Arrows come into the activity from the bottom of the activity.

a. Information System

A series of servers that allow for the registration of users, storage of information, search of available technologies, and execution of those technologies in an open environment.

b. Personnel

The DDSS staff required to facilitate the registration, verification, and interface activities.

4. Control

These are things that constrain the functioning of the activities. Arrows come into the activity from the top.

a. Protocols

Set of established rules between the environment and activities and between activities which allow for shareability and execution of task between the activities.

b. Legal

Legislation which identifies the rights of individuals and mandates responsibilities by those providing services.

c. Validation and Verification Criteria

Criteria established by the decision sciences in the classification and functioning of decision support application.

d. Metadata Requirements

Information required to interface and classify a decision technology.

D. NODE A0: DECOMPOSITION OF CONTEXT DIAGRAM - PROVIDE DISTRIBUTED DECISION SUPPORT TECHNOLOGIES (Figure B-2)

Activity Number:	A0
Activity Name:	PROVIDE DISTRIBUTED DECISION SUPPORT TECHNOLOGIES
Input Name:	Consumers Info, Decision Technology Info, Metadata Requirements, Providers Info
Output Name:	Billing, Distributed Decision Technology, Management Reports, Registration Information, Registration Verification
Control Name:	Legal, Protocols, Validation&Verification Criteria
Mechanism Name:	Information System, Personnel
Sub-activities:	A1 - REGISTER USERS A2 - VALIDATE TECHNOLOGY A3 - INTERFACE TECHNOLOGY
Activity Definition:	Same as A-0

E. NODE A1: DECOMPOSITION OF REGISTER USERS (Figure B-3 through B-6)

Activity Number:	A1
Activity Name:	REGISTER USERS
Input Name:	Consumers Info, Decision Technology Info, Metadata Requirements, Providers Info
Output Name:	Registered Consumers Info, Registered Providers Info, Registered Technologies Info, Registration Verification, Users Reports
Control Name:	Legal, Protocols
Mechanism Name:	Personnel
Sub-activities:	A11 - PRODUCE FORMS AND SCRIPTS A12 - UPDATE DATABASE A13 - PRODUCE REGISTRATION VERIFICATION

Activity Definition: This activity requires the system to capture user data, to include: Consumer registration information, provider registration information, and technology metadata. The initial registration of users and providers is done on-line via HTML forms. The information is then captured and stored in the DDSN database by the use of a scripting language. Updating the database invokes another script which produces a registration verification. This verification is in the form of E-mail and is automatically generated. The metadata required to register a decision technology involves the capture of a variety of information. The system allows for the capture of this information in the same way users are registered. An optional off-line registration form can also be used via E-mail. This information will be captured in the same format (HTML) and be used to update the database as if it were captured on-line.

Activity Number:	A11 (Figure B-4)
Activity Name:	PRODUCE FORMS/SCRIPTS
Input Name:	
Output Name:	Input Forms, Input Scripts
Control Name:	HTML 3.0, SMTP, Metadata Requirements
Mechanism Name:	HTTP Server, Programmers
Sub-activities:	A111 - BUILD FORMS/SCRIPTS A112 - VALIDATE FORMS/SCRIPTS A113 - INTERFACE FORMS/SCRIPTS TO NETWORK

Activity Definition: This activity develops the forms and scripts required to capture user information. The metadata requirements are used to control what is to be captured by the forms. The programmers develop a set of forms to capture the pertinent information and

a series of scripts to update databases and initiate registration verification. The forms and scripts are built, validated, and interfaced to the network during this activity.

Activity Number:	A111
Activity Name:	BUILD FORMS/SCRIPTS
Input Name:	Metadata Requirements
Output Name:	HTML forms, Scripts
Control Name:	HTML 3.0, SMTP
Mechanism Name:	HTTP Server, Programer

Activity Definition: Programmers build forms using an HTML editor or word processor. Scripts are built using Perl scripting language. There are a variety of scripting languages, however Perl is used in this system.

Activity Number:	A112
Activity Name:	VALIDATE FORMS/SCRIPTS
Input Name:	HTML forms, Scripts
Output Name:	Validated HTML forms, Validated Scripts
Control Name:	HTML 3.0, SMTP
Mechanism Name:	HTTP Server, Programer

Activity Definition: Forms and scripts are validated to ensure that they capture the desired information, update DDSN databases, and invoke verification process as described in A1.

Activity Number:	A113
Activity Name:	INTERFACE FORMS/SCRIPTS TO NETWORK
Input Name:	Validated HTML forms, Validated Scripts
Output Name:	Input Forms, Input Scripts
Control Name:	HTML 3.0, SMTP
Mechanism Name:	HTTP Server, Programer

Activity Definition: The validated forms and scripts are then installed within the DDSN. The interface between the DDSS, DBMS and SMTP server is tested and the forms and scripts comprise the registration module of the DDSN.

Activity Number:	A12 (Figure B-5)
Activity Name:	UPDATE DATABASE
Input Name:	Consumers Info, Decision Technology Info, Providers Info, Verification Flag

Output Name: Registered Consumers Info, Registered Consumers Rpt, Registered Providers Info, Registered Providers Rpt, Registered Technologies Info, Registered Technologies Rpt

Control Name: DBMS, Input Forms, Input Scripts

Sub-activities: A121 - ADD NEW INFORMATION
A122 - MODIFY EXISTING INFORMATION
A123 - DELETE INFORMATION

Activity Definition: This activity allows for the addition of new users and technologies, modification of user and technology information and the deletion of registered users and technologies to the DDSN database. The DBMS provides the management tools to the staff of the DDSN in the form of reports, statistics of use, and all information pertaining to users and technologies registered with the DDSN. The database is updated during online registration through the use of HTML forms and Perl scripts. The database is accessed by the users through the HTTP server allowing for a heterogeneous interface.

Activity Number: A121
Activity Name: ADD NEW INFORMATION
Input Name: Consumers Info, Decision Technology Info, Providers Info
Output Name: Added, New Consumer Rpt, New Prov Rpt, NewTech Rpt
Control Name: DBMS, Input Forms, Input Scripts, Legal
Mechanism Name: Database Server, HTTP Server

Activity Definition: This activity allows for all registered users of the DDSN to add new information to the DDSN database.

Activity Number: A122
Activity Name: MODIFY EXISTING INFORMATION
Input Name: Consumers Info, Decision Technology Info, Providers Info
Output Name: Modified, Registered Consumers Info, Registered Consumers Info
Control Name: DBMS, Input Forms, Input Scripts
Mechanism Name: Database Server, HTTP Server

Activity Definition: This activity allows for all registered users of the DDSN to modify existing information about themselves or a technology which they have registered.

Activity Number: A123
Activity Name: DELETE INFORMATION
Input Name: Consumers Info, Decision Technology Info, Providers Info

Output Name:	Deleted, Deleted Consumer Rpt, Deleted Prov Rpt, Deleted Tech Rpt, Registered Technologies Info
Control Name:	DBMS, Input Forms, Input Scripts
Mechanism Name:	Database Server, HTTP Server

Activity Definition: This activity allows for all registered users of the DDSN to delete themselves as registered users and to delete information which they have provided about a registered technology.

Activity Number:	A13 (Figure B-6)
Activity Name:	PRODUCE REGISTRATION VERIFICATION
Input Name:	Registered Consumers Info, Registered Providers Info, Registered Technologies Info
Output Name:	Consumer, Provider, Technology, Verification Flag
Control Name:	Input Scripts, SMTP, SMTP
Mechanism Name:	Email Server, HTTP Server
Sub-activities:	A131 - PROCESS CONSUMER VERIFICATIONS A132 - PROCESS PROVIDER VERIFICATIONS A133 - PROCESS TECHNOLOGY VERIFICATIONS

Activity Definition: This activity provides an e-mail message to the user upon completion of registration, verification, and validation of the user and/or the technology. This action completes the initial registration process for users of the system. Users registering themselves as a consumer or provider obtain an immediate reply if they have successfully registered. An on-line message via the clients WWW browser is sent if the registration was unsuccessful. The registration of a decision technology requires an extensive validation and validation process. The provider of a technology will be sent an interim notice that the information about the decision technology has been received and that the validation and verification process has been initiated. Registration of a decision technology is not completed until the technology has been validated by A2 VALIDATE TECHNOLOGY.

Activity Number:	A131
Activity Name:	PROCESS CONSUMER VERIFICATIONS
Input Name:	Registered Consumers Info
Output Name:	Consumer Verification
Control Name:	HTTP, Input Scripts
Mechanism Name:	HTTP Server

Activity Definition: This activity generates an email message to the user that confirms their registration.

Activity Number: A132
Activity Name: PROCESS PROVIDER VERIFICATIONS
Input Name: Registered Providers Info
Output Name: Provider Verification
Control Name: HTTP, Input Scripts
Mechanism Name: HTTP Server

Activity Definition: This activity generates an E-mail message to the user that confirms their registration as a provider of a decision technology.

Activity Number: A133
Activity Name: PROCESS TECHNOLOGY VERIFICATIONS
Input Name: Registered Technologies Info
Output Name: Technology Verification
Control Name: HTTP, Input Scripts
Mechanism Name: HTTP Server

Activity Definition: This activity generates an E-mail message to the user that confirms the receipt of information pertaining to the technology and that the technology is being verified and the interface is being investigated.

Activity Number: A134
Activity Name: MAIL VERIFICATION
Input Name: Consumer Verification, Provider Verification, Technology Verification
Output Name: Consumer, Provider, Technology, Verification Flag
Control Name: SMTP
Mechanism Name: Email Server

Activity Definition: This activity delivers the appropriate E-mail message to the user.

F. NODE A2: DECOMPOSITION OF VALIDATE TECHNOLOGY (Figure B-7)

Activity Number: A2
Activity Name: VALIDATE TECHNOLOGY
Input Name: Registered Technologies Info
Output Name: Validated Technology, Validation&Verification Reports
Control Name: Legal, Protocols, Validation&Verification Criteria
Mechanism Name: Information System, Personnel

Sub-activities: A21 - CLASSIFY DECISION TECHNOLOGY
A22 - RUN APPLICATION
A23 - VERIFY APPLICATION OUTPUTS
A24 - PRODUCE V&V REPORTS

Activity Definition: This activity is a semi automated procedure to ensure the correctness and accredited the decision technology for use. Intelligent agents and human specialist will verify the model description and classify accordingly. The application will be run against parameters given by the provider. Upon verification, validation, and accreditation, reports are archived and the technology is ready to be interfaced to the DDSN.

Activity Number: A21
Activity Name: CLASSIFY DECISION TECHNOLOGY
Input Name: Registered Technologies Info
Output Name: Classified Technology Info
Control Name: Legal
Mechanism Name: Decision Support Specialist

Activity Definition: Activity categorizes the application. The registered technologies info is used to identify the type of application and the functional area that it can be used in. The application is given an appropriate classification which will be used for indexing and cross referencing.

Activity Number: A22
Activity Name: RUN APPLICATION
Input Name: Classified Technology Info
Output Name: Application Outputs
Control Name: Protocols, Validation&Verification Criteria
Mechanism Name: Decision Support Specialist, Information System

Activity Definition: The application is run remotely to validate operation

Activity Number: A23
Activity Name: VERIFY APPLICATION OUTPUTS
Input Name: Application Outputs
Output Name: Report Data, Validated Technology
Control Name: Protocols, Validation&Verification Criteria
Mechanism Name: Decision Support Specialist, Information System

Activity Definition: Output of the application is compared with the expected given at registration to ensure correctness

Activity Number: A24
Activity Name: PRODUCE V&V REPORTS
Input Name: Application Outputs, Classified Technology Info, Report Data
Output Name: Validation&Verification Reports
Control Name: Validation&Verification Criteria
Mechanism Name: Decision Support Specialist

Activity Definition: Reports are generated for validation, verification, and accreditation process for each application registered and accepted for use.

G. NODE A3: DECOMPOSITION OF INTERFACE TECHNOLOGY (Figure B-8)

Activity Number: A3
Activity Name: INTERFACE TECHNOLOGY
Input Name: Registered Technologies Info, Transaction Request
Output Name: System Statistics, , Distributed Decision Technology
Control Name: Legal, Protocols, Validated Technology
Mechanism Name: Information System, Personnel
Sub-activities: A31 - IDENTIFY INTERFACE REQUIREMENTS
A32 - BUILD INTERFACE
A33 - DISTRIBUTE DECISION TECHNOLOGY
A34 - MONITOR USE OF TECHNOLOGY

Activity Definition: Allows users to access registered decision technologies by providing a common interface to the provider of the decision technology. The interface will be dependent on the type of technology and the type of servers computer assets available at the providers site. The registered technologies info identifies all inputs required and outputs of the technology. If the provider is classified an independent technology, the interface is nothing more than an HTML form which will reside within the DDSS file directory structure. If the technology is exclusive a series of scripts and HTML forms will interface the application with the HTTP server at the DDSS. The provider must provide a combination of servers to allow for data transfer from the consumer, output back to the consumer, and a DNS to allow activation of application possibly through a transparent Telnet session. This interface allows for transparent connection, data transfer, and execution of technology. A feed back activity is also required to monitor the use of any given technology. This is required for billing of both consumer and providers and to track resource requirements.

Activity Number: A31
Activity Name: IDENTIFY INTERFACE REQUIREMENTS
Input Name: Registered Technologies Info
Output Name: Type of Interface

Control Name: Legal, Protocols, Validated Technology
Mechanism Name: Decision Support Specialist, Programer

Activity Definition: This activity identifies the type of technology that has been registered and verifies the correctness of data given at registration. If data is incomplete, the POC is contacted and the information is solicited. After all information is available , the data is sent to the Build Interface activity for automatic setup of the application to the DDSN.

Activity Number: A32
Activity Name: BUILD INTERFACE
Input Name: Registered Technologies Info
Output Name: Specific Technology Interface
Control Name: Protocols, Type of Interface, Validated Technology
Mechanism Name: Decision Support Specialist, HTTP Server, Programer

Activity Definition: Presently a manual process, but automation is envisioned. A series of CGI scripts and HTML documents make up the interface. An exclusive technology will have the files sent to the providers server. An HTML file summarizing the input data will also be maintained at the DDSS. This file is the application entry file for consumers of the network. The final product of the build interface activity is a distributed decision technology.

Activity Number: A33
Activity Name: DISTRIBUTE DECISION TECHNOLOGY
Input Name: Registered Consumers Info, Registered Providers Info, Registered Technologies Info, Transaction Request
Output Name: Distributed Decision Technology
Control Name: Protocols, Technology Interface
Mechanism Name: Decision Support Specialist, HTTP Server, Programer

Activity Definition: This a control activity which allows registered users to use registered decision technologies. The login of users is also done at this activity. A good analogy here is a menu. The user is provided a list of options (register, login, use a technology), through a transaction request the appropriate activity within this activity is initiated.

Activity Number: A34
Activity Name: MONITOR USE OF DECISION TECHNOLOGY
Input Name: Distributed Decision Technology
Output Name: Billing
Control Name: Protocols
Mechanism Name: HTTP Server, Programer

Activity Definition: This activity tracks the usage of all users of the system. The output is system statistics which is sent to other processes such as billing and resource usage.

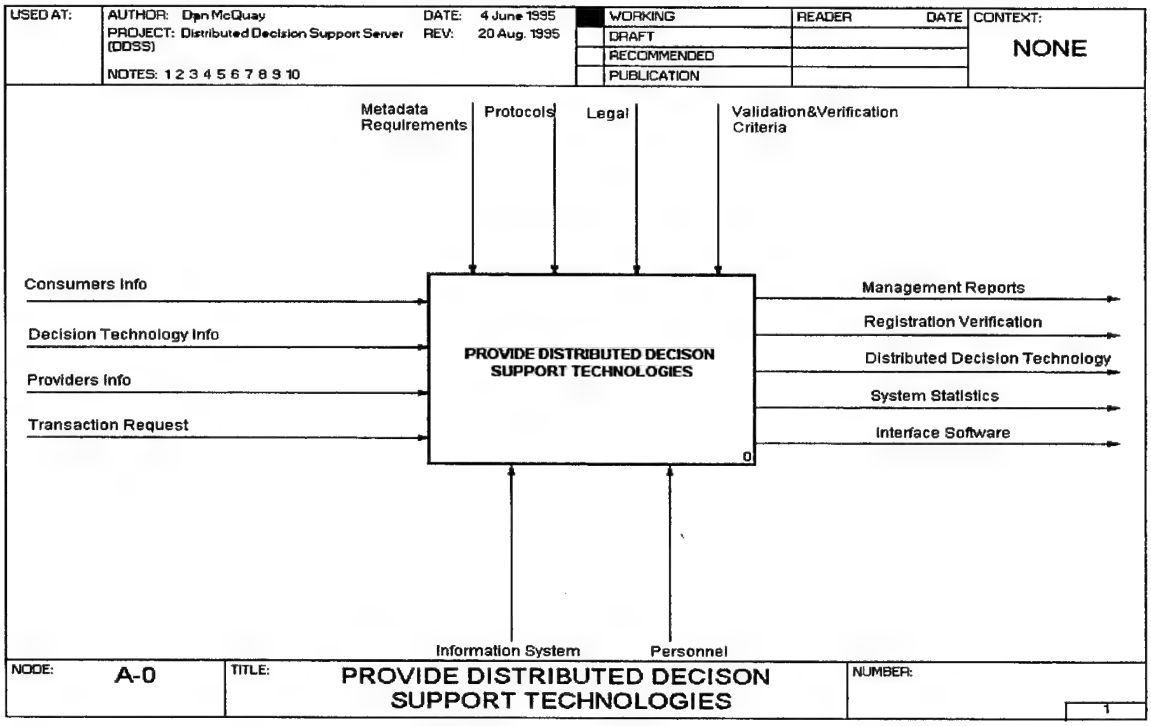

Figure B-1. DDSS Context Diagram (Node A-0)

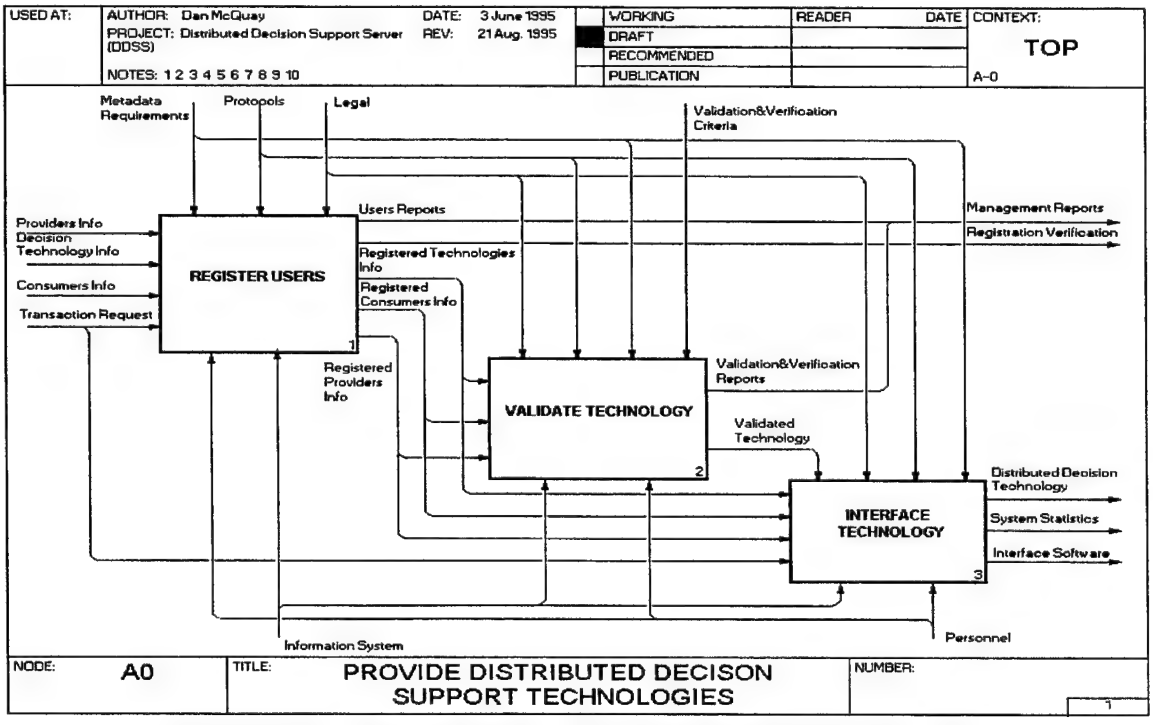

Figure B-2. Decomposition of Context Diagram (Node A0)

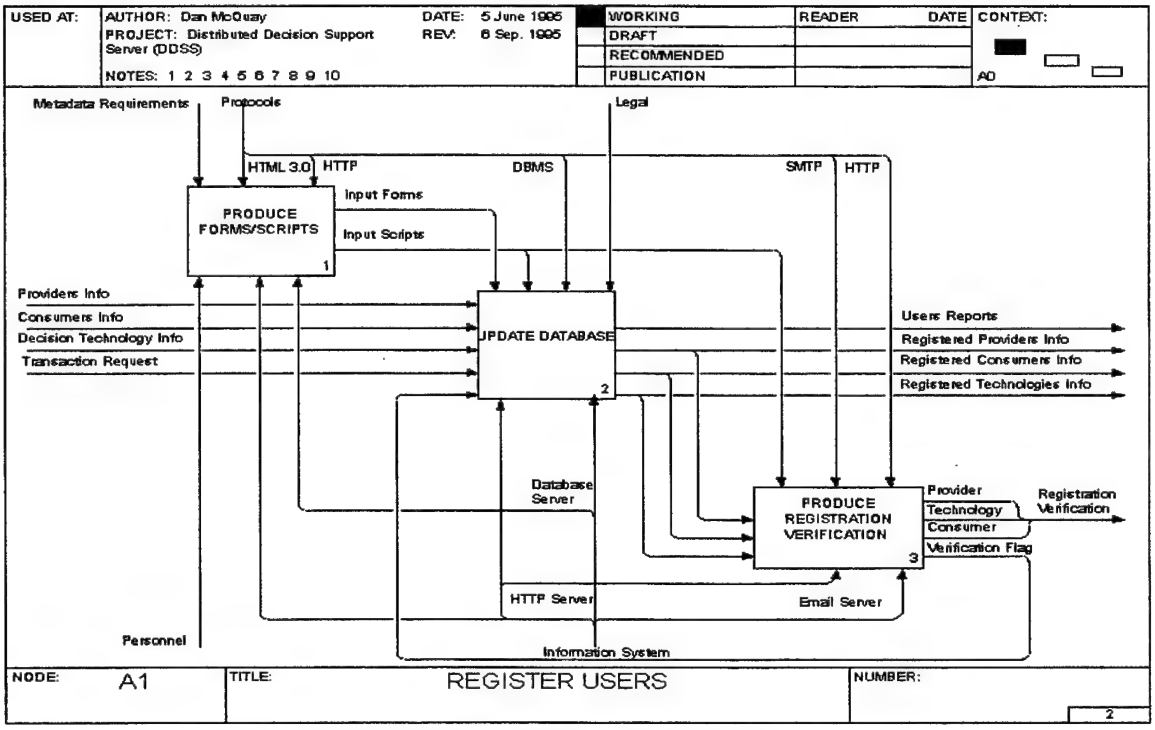

Figure B-3. Register Users (Node A-1)

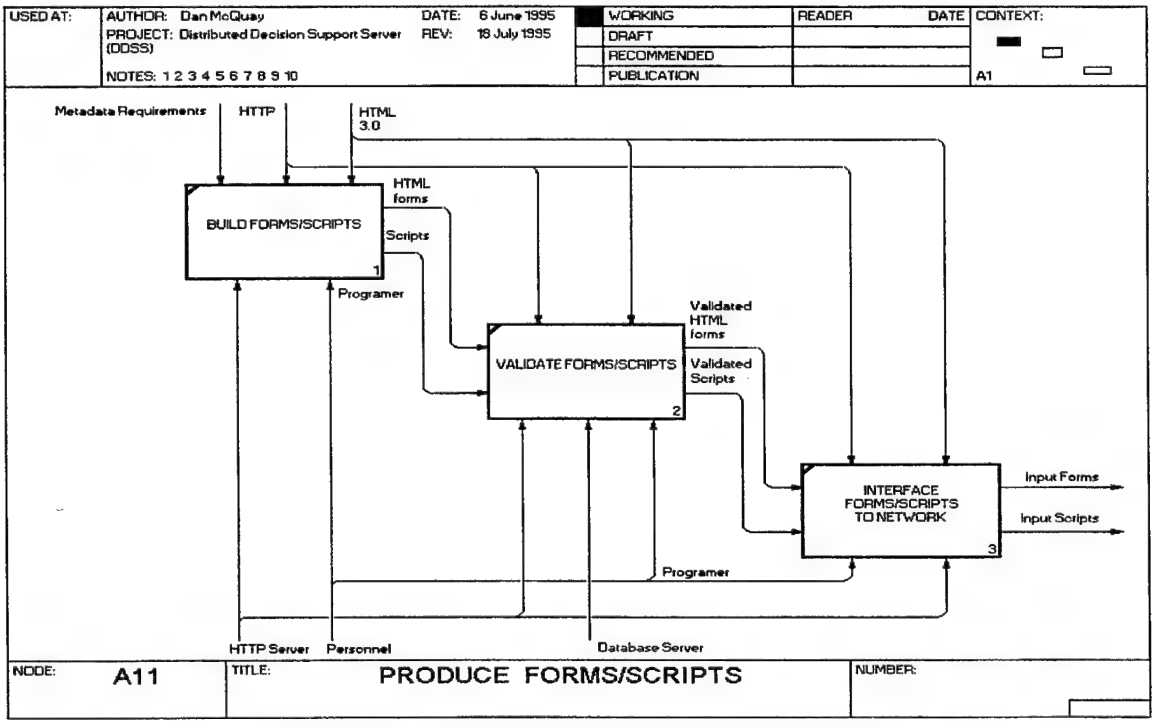

Figure B-4. Produce Forms/Scripts (Node A11)

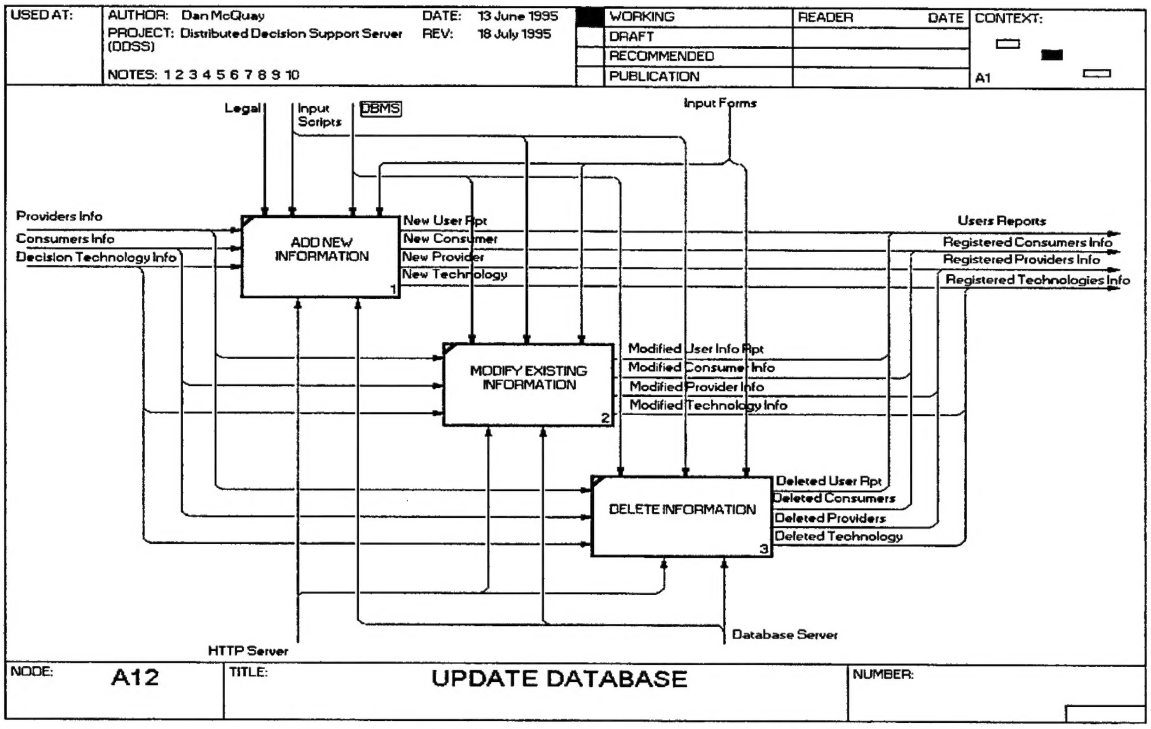

Figure B-5. Update Database Node (A12)

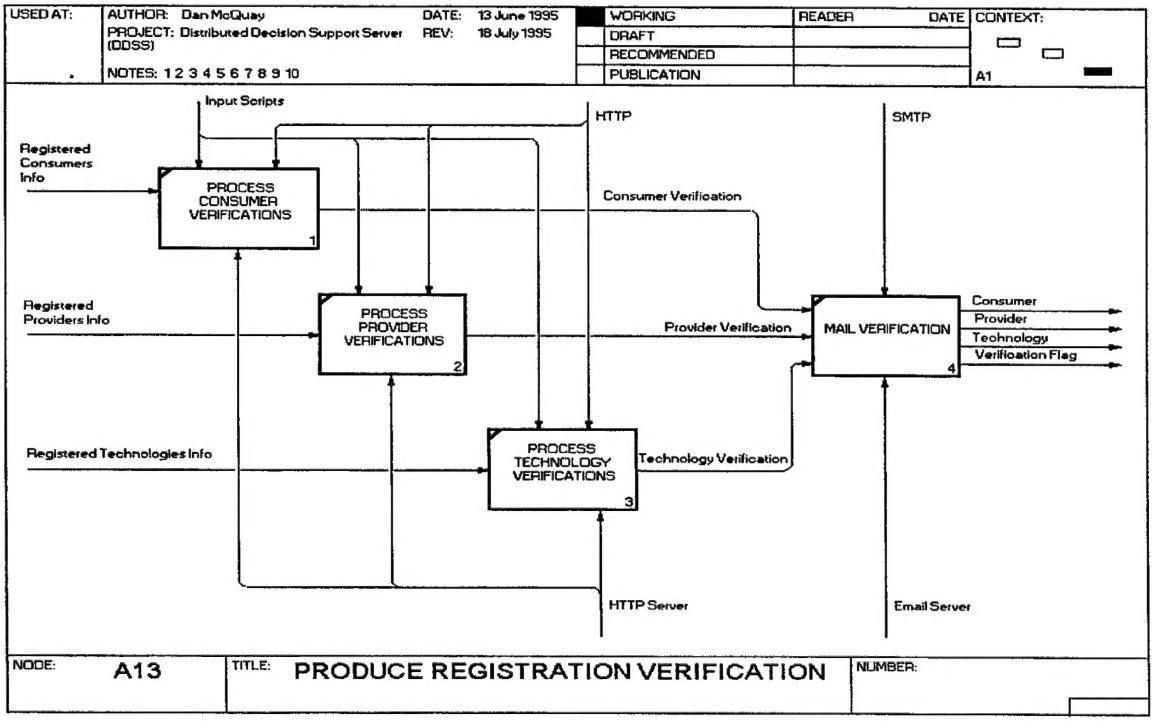

Figure B-6. Produce Registration Verification (Node A13)

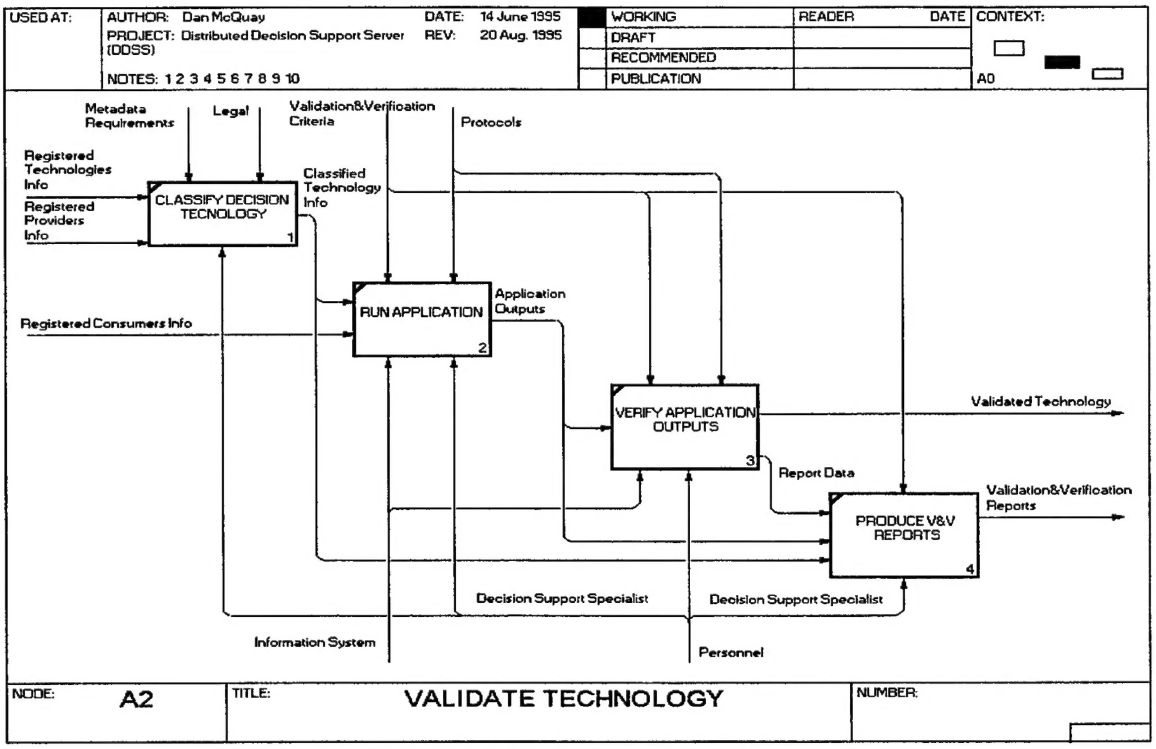

Figure B-7. Validate Technology (Node A2)

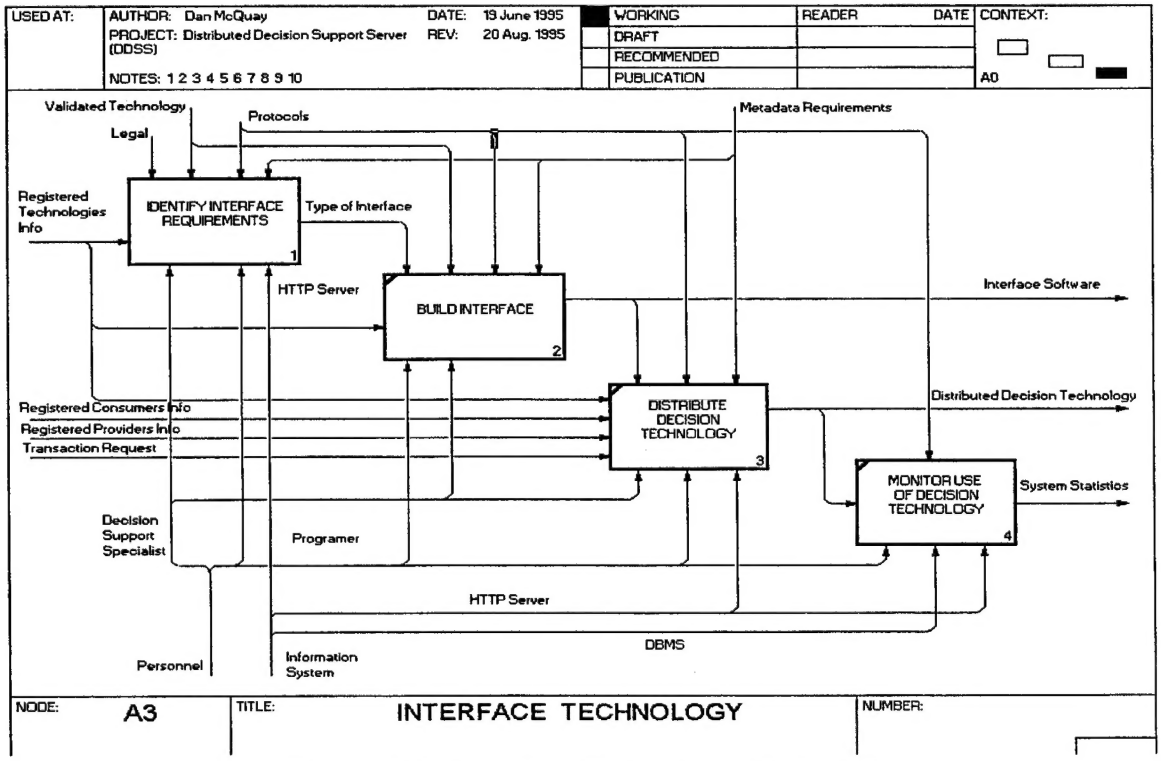

Figure B-8. Interface Technology (Node A3)

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   Naval Postgraduate School
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8. MCCDC, WCSD (Code: C471) 1
   2076 South St.
   Quantico, VA 22134

9. MARCORSYSCOM, Program Support Director (Code: PSA) 1
   2033 Barnett St.
   Quantico, VA 22134

10. Mr. Nicholas Nayfack (Code 4121) 1
COMPASS Project Deputy Manager
NraD
San Diego, CA 92152

11. Commanding Officer, Defense Modeling and Simulation Office 1
ATTN: LtCol Barnett
1901 North Beauregard Street, Suite 504
Alexandria, VA 22311-1705

12. Professor Ramayya Krishnan 1
The Heinz School
Carnegie Mellon University
Pittsburgh, PA 15213

13. CAPT George Zolla (Code 05B) 1
Naval Postgraduate School
Monterey, CA 93943-5101

14. Captain Dan McQuay 2
1 Wexwood Ct.
Stafford, VA 22135